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Plastics

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On Climbing Hills

AFTER some 15 or more years of watching from within and without the struggles of the plastics industry to establish some recognition in the normal life of the community, one can regard its progress with a certain amount of clarity.

While the feelings of those in the plastics industry may not be quite those of stout Cortez when he climbed his hill to see the Pacific Ocean, or those, of ancient Biblical times, who first saw the promised land, yet our workers have reached a prominence from which they can at least see, in fairly broad expanse, the world yet to be conquered.

The rapidity with which it has developed has amazed and confounded the critics and even the industry itself, and while the plastics historian may point to the war as being an accelerator par excellence, yet the curve of production and of "versatility" had been rising steeply in peace-time.

No doubt the sequences in the plastics industry have followed many of those in other industries based on scientific endeavours. In the early days, came the first concrete descriptions in the scientific Press, and the organization of a manufacturers' and traders' circle to protect their interests, as typified by the British Plastics Federation. Almost contemporaneously came the need for scientific bodies to discuss its own special scientific industrial problems, and the Institute of the Plastics Industry was formed.

By 1927 the plastics industry was strong enough to have its own small corner in the Chemical Section of the British Industries Fair in London, but it grew so rapidly and steadily that by 1931 the area taken by its exhibition had reached an imposing size, and the type of exhibit had changed and expanded greatly in character. Plastics had left the chemical nest and had set up a home on their own.

So far its history differs but little from any other that has grown up on a scientific-cum-engineering basis, and were plastics merely chemicals in which man has no interest as such, their position in the world to-day would be very different. It is the finished moulding, with its close relation to the man in the street, the artist, the architect, the ship and aircraft builder, the engineer, in other words, to all mankind, that has lifted plastics out into the open.

Recent happenings show how far we have gone, show the prominence of the hill we have climbed. Perhaps we should first mention the appearance of the advertising of plastic materials in the daily and other newspapers. This step, which had been taken even pre-war by one or two of our largest manufacturers, is of profound importance, indicating two facts, first that in finance and in production the industry is sound and growing, and secondly that the industry itself realizes

the importance of showing and teaching the public what plastics are.

Perhaps of equal importance is the fact that plastics are being talked about on the radio by experts that have been asked by the B.B.C. to do so. The excellent examples set recently by Mr. Frank Merriam, of BX Plastics, and by Drs. H. Barron and V. E. Yarsley, the well-known plastics consultants, will no doubt give the B.B.C. courage to continue the same subject. In a more restricted field, the lectures by H. V. Potter, C. Chapman, Dr. Caress and others to the shipbuilding and other engineering worlds have broken down many barriers.

In our opinion, a more striking pointer than any of the above, for the value of the radio and lectures do not bear immediate concrete results, is the fact that for three years past the Society of British Aircraft Constructors, Ltd., have honoured the plastics industry with a technical display of plastic materials used in aircraft production. The last exhibition was held on July 29 and 30, at Grosvenor House, Park Lane. It was a private view for aircraft constructors alone and therefore cannot be discussed in these pages, but we have certainly passed a milestone in plastics history. We have reached the top of our first hill.

Tokens in Plastics

THE Oxford Dictionary contains the following meanings of the word " token ": Sign, symbol, evidence (of affection); . . . keepsake, coin, etc., serving as proof of authenticity . . . piece of metal like and used instead of coin, but worth much less than nominal value and issued by tradesmen, banks, etc., without sanction of government.

Tokens have been used from time immemorial—they were quite general in ancient Biblical times, by the early Christians in Rome, by Ghenghis Khan, who gave lovely gold ones to those who wished to pass over China, by King's Messengers and writers of spy stories, and by shady night clubs. Some of the loveliest tokens were those used in happier days by the gambling casinos in France. The Monte Carlo 100, 500, and 1,000-franc tokens were of cellulose acetate and beautifully designed and coloured.

A short time ago we came into possession of a non-metallic token issued by the Sheffield Transport Department on its Corpora-

tion tramway system. We had imagined that the token idea had long disappeared in the industrial sphere (our last acquaintance of them were tokens for a ½d. fare used in 1914 in Kent) and made further inquiries. The tokens in Sheffield are very much in use and have been for over 15 years—for some employers of labour prefer to issue them instead of ordinary coinage to employees who have to travel on Corporation vehicles in the course of their duties. The tokens are prepaid instead of ordinary coinage and available to any one on application. The real reason for their use is, perhaps, obvious to our readers. It is also interesting to note that these Sheffield tokens are made of Fiberloid. Presumably this is the trade mark of the Fiberloid Corporation, U.S.A., which manufactures celluloid. The latest development in token production and usage is a peculiarly war-time one—in connection with

the new British Restaurants that are springing up all over the country. During a recent visit to the works of Crystallate, Ltd., we saw thousands of them being produced by injection moulding from cellulose acetate. They are made in a variety of colours, each representing different values, and each being exchanged for its value in food at the counter.

Plastic Building Components

With Special Reference to Interiors and Furniture

The modern trend of furniture manufacture is discussed and the possible place of plastics in the movement defined

By GEORGE FEJÉR

IN the previous notes we commented upon the aspects of plastic building components on a general basis, irrespective whether these may be used externally, in the interior, or invisibly hidden in the construction. The present notes are meant to deal with some of the problems which arise if we ask ourselves what part are plastics going to play in the shaping of the post-war interiors. Whatever the type of building, it is apparent that the soundness and character of the interiors is just as important as the main structure or outside appearance. The majority of the general public is even more concerned about the interior of domestic buildings than about the structural features.

So far as plastics are concerned, there is already much experience in the manufacture and use of plastic interior components. The natural manner of development appears to be the promotion of interior uses of plastics still further until there is sufficient experience (not only in the manufacture, but also in handling) to go over to more difficult jobs, such as roofing, or structural units of the building. It is obvious that not an ounce of synthetic resin, and not a single machine, can be spared now for the manufacture of unessential items of the interior decoration; it may be not too early, however, to give some thought to technical and industrial considerations concerning both the immediate future and post-war development of interior components.

The immediate future.—There is a growing need for sound, practical, well-designed interiors in hostels, nurseries, hospitals, communal centres, as well as in homes. It is hoped that "Utility Furniture" will satisfy the most urgent needs. It is too early to tell, however, whether the drive for utility furniture will result in the production of cheap bedroom and dining-room suites, on much the same lines as these have been made in the past or whether it will lead to a more close investigation of the design and construction of interiors. There are reasons to hope that the official guidance will succeed in developing the best solutions, and that the designs and materials will be devised on a scientific basis. We read in the daily Press that the use of plastics is being investigated closely.

Post-war Development

In conjunction with post-war problems of interior architecture, there are several questions which spring to mind:—

What advantages would the use of plastics entail?

Can plastic furniture be mass produced?

Will the development of plastics influence the design and æsthetical features of the interiors?

There are many questions like these, and there must be more specialized research until we are able to define the proper place of plastics between the older materials. Let us hope that there will be no sideboards or dining tables compression moulded from wood flour-filled resins—all in one piece.

The way from the moulding powders to furniture is a difficult one, and it is highly probable that the wood-working industries, cabinet makers, will find in plastics a new partner rather than a competitor. New techniques of fabrication of plastics are being devised, and once the technical benefits of new industrial processes become available to the craftsmen and

designers, they will be able to develop the art of using plastics.

It is, therefore, necessary to set the course of the specialized research first, in order to develop and improve industrial processes.

The components of the interior wall covering, floor-covering equipment, etc., are essentially building components. Some of these are again suitable for vehicle and shipbuilding. Therefore, any investigation in relation to interiors and furniture is equally suitable to promote development in other fields of construction. The treatment of walls of interiors, partitions, etc., with plastic materials have become fairly popular already. Paper-based urea and phenolic resin boards have been found useful for panelling and wall-covering, and at the same time the sheets of this type are useful for many other purposes, including cabinet making (table tops, etc.). The fabric-based impregnated sheets (such as the cellulose nitrate and acetate-impregnated fabrics) have been used for a large variety of purposes in the past 20 years, and the versatility of such sheets as protective and decorative materials (over wood and metal) has been sufficiently proved. The aspects of the extruded plastics are by no means confined to any particular field of use, and there are many varieties of sections especially designed to meet the cabinet-makers' requirements, both thermoplastics (such as, say, cellulose acetate butyrate) and thermosetting resins have been produced to meet the demand for laths, trims and coverstrip-"mouldings."

The numerous items in domestic equipment, from refrigerators to switches, are well known to the public in many varieties of plastics—from injection moulded polystyrene to cast phenolics, and there will be, no doubt, a fair choice of plastic articles at the disposal of the interior architects when the time comes for reconstruction.

Although the above examples illustrate that furniture, interior and building, are all parts of the same problem, for a closer investigation let us concentrate on the question, what part is plastics going to play in the manufacture of furniture?

The Components of Furniture

With certain simplifications, the components of which all furniture is built up can be divided roughly into two large groups, such as the:—

Rigid sheets.
Frames or frame elements.

The system of using rigid frames plus panels is still the classical way of using solid wood. Naturally, the laminating and veneering technique developed in the last three centuries to an extent that it became possible to do away with many framing elements which were necessary when solid wood was used.

Rigid sheets, such as blockboards, provide a dimensionally stable element (flush doors, table tops, etc.), without any further framing. The high expansion and shrinkage in the radial and tangential directions to the year rings of the solid timber have been minimized to practically a negligible degree by laminated sheets of the "blockboard" and "laminboard" type. The progress made by the introduction of synthetic resins as a bonding agent in plywood indicates that we shall see more development along these lines.

The frames, such as the framework of wardrobes, doors, chairs, tables, etc., are still being joined from straight solid elements together. Whether these frames are made invisible by covering with plywood panels, in the modern way, or whether the rails are grooved to hold a solid panel in the classical manner—*the frames are being made on practically the same principles as seven centuries ago*. It is neither necessary or possible to do away entirely with the framework system of chairs or tables for instance, but there is ample space for improvements to provide frames which are jointless. And that is the point where the help of the modern laminating methods and synthetic resins are going to play an essential part, to make the "building up" of frames possible.

Fig. 1.—Laminated armchairs made on the Aalto system.
("Daily Mail" Ideal Home, 1940.)

Jointless Frames

We have indicated that the advance made in the manufacture of the frame and skeleton work of furniture was far less spectacular during the past three centuries as compared with the improvements which have been made on the quality of laminated rigid sheets.

Take, for instance, the example of chairs. The proper use of solid wood, treated and shaped by simple tools, has led to the design of "Windsor chairs." This, we presume, will never go out of fashion so long as the "standards" of the human body and the habit of sitting down prevail and so long as there are craftsmen who understand how to select and use solid wood. The only advance made in the manufacture and economy of mass producing skeletons and frames of chairs was the "thermoplastic" treatment, that is, steam bending of straight elements, a method which has been developed in the past on a really large scale, and has provided a considerable proportion of our mass-produced articles from office chairs to umbrella stands, etc. The process, however, does not allow much flexibility in the design, and the development of other than utilitarian types has not been quite as successful. There was a new drive, just before the war, to expand the scope of this process. It is obvious that there is a disadvantage in the steam bending process of straight solid elements, since these tend to regain somewhat their original form unless held securely in position.

Another far more interesting technique, which has been practised in the past 10 years, is based on the system and designs developed by the Finnish architect Alvar Aalto. Fig. 1 shows a number of Aalto armchairs, which were made some 10 years ago. Both the seats and the frames are made of laminated wood, the frames consisting of fairly substantial laminæ. The sheets have been bent first to the required shape and subsequently glued. The laminated product thus made resembles tube from which slices of various "thickness" can be sawn.

(The process thus resembles the procedure when napkin rings are cut from extruded or cast resin tubes.)

The armchairs are perfectly rigid, although the seats are slightly springy, as they are built up from thin veneers to overall thicknesses similar to that of plywood. Naturally there are many other types of furniture units developed on similar lines by Aalto, chairs and tables in particular. There is one type of chair which is a particularly interesting example of the system, having the same type of bent jointless frame as metal-tube chairs, and just as springy. The bent frame elements shown in the illustration (Fig. 2) are

American examples. According to the United States Plywood Corporation, any desired length can be obtained of these sections. These sections, or "stock-moulds," have been developed especially to suit the requirements of chair manufacturers. The glue used in the manufacture is phenolic resin.

The two examples cited are sufficient to indicate the line of development which

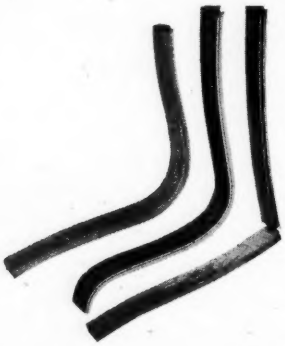

Fig. 2.—Standard continuous back and seat forms.

can be expected in the manufacture of jointless wood-plus-resin frame structures.

Future Development in Wood-plus-resin Structures

It may be regarded as possible to do away entirely with the principle of building up furniture from rails (frames) and rigid sheets, by using plastics throughout. It is indeed quite possible, for instance, to make doors and bodies of small cabinets by the compression moulding process. Refrigerator doors, radio cabinets, and many similar items have been compression moulded by using thermosetting resins, or injection moulded by using a thermoplastic resin such as, say, polystyrene.

This procedure is, however, only justified when the number of the repetitions is sufficiently large to make the provision of the moulds worth while. This is only one consideration. The other and even more important limitation is that the public has the right to expect individuality, originality and variety in design of furniture.

We thus come up against the contrast between individuality and standardization, and we may be sure that standardization of the design of finished furniture is not desirable by the public. The craftsmen, the interior architects and the wood-working industries can and will give the public better solutions than rigidly uniform patterns. Standardization is only necessary on the "manufacturing end" of the story, as an economic factor. Certainly there are many items which can be and will be made in one single operation, without running the risk of being condemned as too stereotyped. (See under the heading "All Plastic Components.")

It seems obvious to the writer that plastics should provide half-finished articles and components for the use of the interior architects and craftsmen. The principle which may satisfy all those who are concerned in using (as well as making) furniture, may be summed up as follows: standardization in the manufacture of the half-finished article on the one hand, variety and individuality in the marketed product on the other.

For the manufacture of such half-finished components, let us consider the combination of wood and synthetic resins, since it is clear that wood always was and still remains the best raw material for making furniture. Naturally there are certain exceptions; for instance, steel furniture is practical and popular for offices, hospitals, etc. For the home, steel furniture will, however, never be as popular as the enthusiastic modernists hoped some 10 years ago. The warm touch, the easy repair, the pleasing surface, the wearing qualities of wood furniture cannot be surpassed.

Plastics have already played a large part in improving the glueing technique in laminated wooden structures, and the next step seems to be nothing more—or less—than to revolutionize the laminating technique altogether.

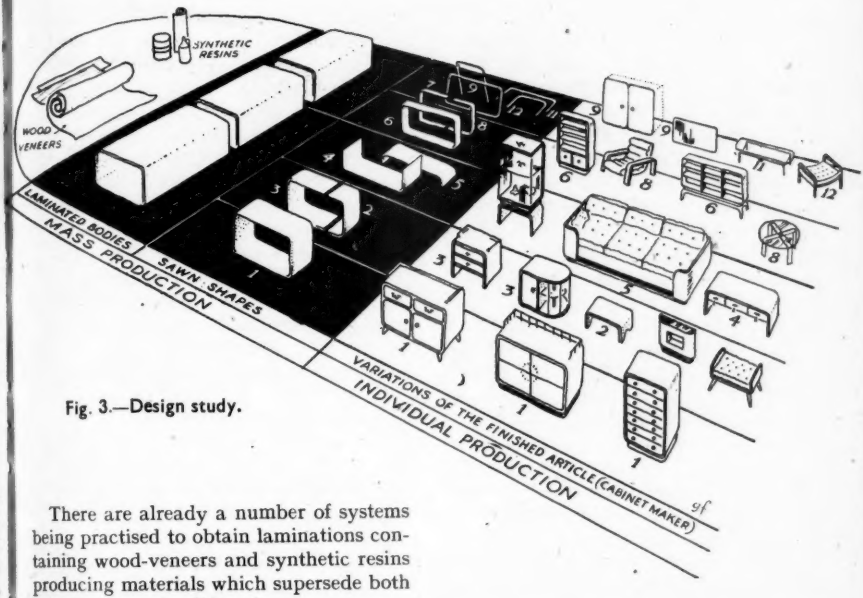

Fig. 3.—Design study.

There are already a number of systems being practised to obtain laminations containing wood-veneers and synthetic resins producing materials which supersede both solid wood and solid resin.

To obtain the best possible solutions, standardized in the manufacture but varied and original on the user's end—research must be threefold. The systematic examination of designs, the choice of the best resins, and the search for the most suitable laminating technique and type of wood are three important factors. These are so inter-related that we have to create an example by illustrating it. The sketch (Fig. 3) may convey the idea how wood-veneer and synthetic resins can be combined to form laminated "stock-moulds" which provide a wide range of furniture components. The writer has chosen a simple oblong shape-section (with rounded edges) for the present investigation, merely to form a basis for the close investigation of what he really means, by stressing the inseparable nature of design, plastics and processes in this particular case.

(a) Design-considerations

It can be seen that the success or failure of a scheme such as sketched in Fig. 3 depends to a large extent on the dimensions of the section, however simple. The radius of the curved corners largely depends on the methods and processes which can be practised, but even this is essentially a design problem. Therefore it is quite inevitable that rough layouts must be made of at least twice as many design studies of the finished articles as is given here, before even considering any particular sort of wood, synthetic resin, etc., as raw materials, and before deciding on the manufacturing process to be used. It may not be necessary to lay down hard and fast rules how the cabinet maker should finish the articles, but typical examples have to be worked out in advance with the utmost care of the dimensions, as this "design research" will decide every feature of the stock-moulds. By close examination of the sketch (Fig. 3) it will be found that, for instance, the thickness and the number of laminations which may be sufficiently strong to suit requirements as continuous jointless frames (as illustrated by the

sawn shapes numbered from 9 to 12), would be far too expensive and wasteful for uses for which the shape 1 can be put. It must be borne in mind that when the stock-moulds are sawn, all layers become visible; this makes the choice of veneers and the choice of the plastics used subject to a special study from point of view of colour, polishing and glueing considerations. In the last row of the sketches a double-door of a built-in wardrobe is indicated, as deriving from the frame unit 9. If the jointless frame (9) is covered on both faces with plywood or similar semi-rigid board to provide these doors, in all probability the sheets will have to be glued to the frame to give a flush surface. The glue which has to secure the sheet to the frame has to bond equally well to the wood veneers as to synthetic resins. If that condition is not being met, the edge of the laminated structure would be regarded like the "end grain" of the solid wood, which is very undesirable.

It is likely that the most versatile and useful stock-moulds are not those with the simplest sections. Naturally a laminated tube with circular section can be put to many uses, but without the design-research the suitability for one purpose or another is more or less left to chance. Laminated plywood tubes with circular sections are already being made in certain diameters and specific thicknesses to suit requirements which have been carefully investigated in advance. The most promising shapes will be probably those suitable for the manufacture of doors and light chairs. In the case of chairs the design of stock-moulds is greatly aided by the natural standards of the dimensions.

In certain cases the design-analysis will have to be carried out in the opposite way, when existing shaping-presses will become available for the manufacture of furniture components—after the war.

(b) The Choice of the Suitable Plastic

It is hardly possible to determine off-hand what plastic should be used and in what ratio to wood in a laminated structure such as represented by our example illustrated on the layout Fig. 3. A set of circumstances such as the available plant, the available heat, the required speed and quantity of the production are deciding factors besides the availability and comparative costs of the various plastic products.

The plastic can be incorporated as a liquid or as solid interlayers and the process of lamination (in its variations) may require an air-drying or rapid-setting material. There has been a tremendous development already in the field of producing plastic substances for such purposes, both here and in the U.S.A., and from the wide range of these materials let us only mention a few which can be considered as suitable for carrying out the suggested laminated shapes.

Plastics in Liquid Form

The development of the urea and phenol-formaldehyde glues for use in plywoods needs no further comment, as it is generally known how these resins have improved upon certain qualities of plywood structures. For our consideration, however, it is not the weathering question which makes the use of urea and phenolic resins preferable to animal or casein glues, but the aim at a better dimensional stability. It is, of course, a quite important consideration that the wet-strength-percentage figures for both the phenolic and the urea glues are more favourable than those obtained with either animal or casein glues. According to A. G. Knight,[1] certain comparative tests have shown that the plywoods cemented with the thermosetting resin had an overall wet-strength of approximately 75 per cent., whilst the specimen glued with a certain casein glue failed above the mark of 17 per cent. In furniture, soaking or boiling does not come into the picture seriously, but steam and damp may be regarded as serious enemies of laminated frame sections. With the p.f. and u.f. resins we may expect a lamination of good

dimensional stability under all normal conditions.

Both the above-mentioned resins are available in a good range of working temperatures. "Catacol" cold-setting phenolic glue has been described in greater detail on these pages[2] with special regards to its aspects in boat-building. The two-part glue sets at normal shop temperatures. There are other phenolic glues in the Rockite range of plastics which harden at low temperatures. It is interesting from both the small craftsmen's point of view as well as for the householders, that urea cold-setting glue is being marketed in the U.S. in the form of powder which can be mixed with water to form a durable glue, according to newspaper reports;[3] and an article which appeared in the "Scientific American."[4] Beetle urea-glue, which is of the water-soluble variety, has been extensively tested in the experiments carried out at Princes Risborough with special regards to the possibility of using the liquid for softening veneers. Thus these water-soluble mixtures appear to be especially suitable for the "building up" of shaped laminated bodies, as modifications in the steam-treatment or hot-water treatment are possible and in certain cases it may be possible to use the glue as an impregnant which at the same time acts as a softening agent and adhesive.[5]

The paper-based p.f. and u.f. resin adhesive films may be easily applicable for such jobs as our example, at appropriate temperatures required for the work with such films. Similarly the foamed variety of urea resin[6] may be adaptable for the purpose to produce a lamination with the least amount of synthetic resin; this type of urea glue is particularly suitable for cementing thinner veneers in hot-water-heated presses.

Whilst the thermosetting resins are available in a wide range of bonding plywood, thermoplastics are less often used as bonding agents. Vinyl-polymers or acrylics may be certainly worth investigating for building up curved laminations. The incorporation of plastics between the wood veneer layers is by no means confined to the field of adhesives. There are already many a laminated product on the market which contains a higher resin-wood ratio, as solid sheets of certain plastics as well as plastic adhesives. By raising the resin content, the specific weight of the resulting product necessarily exceeds the weight of solid wood, and there are certain products which contain low-density fibre laminæ as well as resin sheets and wood veneer, presumably to obtain a lighter product.

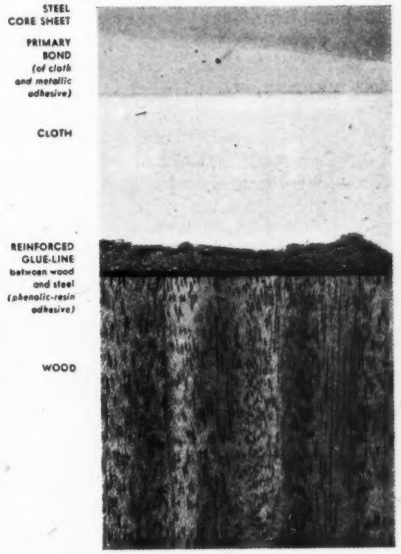
STEEL CORE SHEET
PRIMARY BOND (of cloth and metallic adhesive)
CLOTH
REINFORCED GLUE-LINE between wood and steel (phenolic-resin adhesive)
WOOD

Fig. 4.—Steel veneer sheet (Robertson's Bonded Metal).

For the purpose illustrated by our example, the use of thermoplastic sheets seems to be practicable as plastic interlayers between wood veneers.

The use of muslin-like fabrics can be incorporated for carrying the agglutinants, and also as reinforcements to prevent cracks in the veneers. The use of muslin in the manner it is now being used for covering plywood surfaces externally[7] in certain building components

would hardly be suitable for our present consideration.

Besides wood, synthetic resin adhesives, thermoplastic sheets and fabrics, the use of metal-layers may be considered to produce laminated bodies of high strength. This procedure has been made possible thanks to the versatility of certain phenolic resins, and metal-wood combinations are being manufactured on a full commercial scale. If we suppose the tube-like laminated body shown on our sketch to be built up with a thin steel-sheet with internal lining, certain obvious advantages present themselves in the use of the sawn shapes for quite different articles from those illustrated on our design study.

When we say metal-wood combination we think essentially of the bond between a single veneer and a metal-sheet rather than one metal-faced plywood. The versatility of such a pliable wood-metal sheet in the manufacture of laminated structures is really unlimited. Fig. 4 shows a veneer-steel combination of this kind, which is known under the trade name Robertson's Bonded Metal (USP), and it is stated that the sheets can be handled and applied as steel-sheets, and the metal-face can be fixed even by spot-welding. The sheets are extremely pliable, the radii of bent shapes can be kept small (1-in. radius appears to be the limit in one direction). The photograph shows that the bonding of steel and veneer has been solved by introducing a fabric-layer and phenolic resin.

This very brief survey of the possibilities in the choice of the resins and sheets which can be used to build up the laminated bodies in addition to wood veneers (they should still form the main basis), shows that the range of the available materials is wide enough to provide products "made to measure." Practically all characteristics of the resulting products can be varied at will within certain limits; the strength, the appearance, the workability can be predetermined by suitable combination of the laminæ.

The Laminating Processes

There is nothing new in the principle of building up laminated structures of slightly curved sections, and many of the generally known veneering or laminating processes are adaptable for producing shapes such as suggested above. The difficulty arises, however, by the fact that the shapes should be continuous, jointless laminated bodies with rounded edges. The extensive tests carried out by the Forest Products Laboratory in Madison, U.S.A., as well as in Princes Risborough in this country, on continuous bending and shaping possibilities of veneers, throw a new light on the possibilities given by thermosetting resins.

The problem, how to combine the proper thicknesses (say, from 1-80 in. to $\frac{3}{8}$ in.) of the rotary cut veneers with the proper plastic may be decided, to a certain extent, by the available plant. It depends much on the ingenuity of the manufacturers how to utilize existing presses or other facilities to the best result. However, certain principles which are being practised in building up laminations may be well worth a brief summary.

Light Pressure.—The ancient method of using sand-boxes or sandbags as cauls to hold veneers firmly on a curved groundwork until the glue has set is a system which has found its modern variations. Let us only mention here the system of using a rubber sheet as the external mould which, on production of a vacuum under the sheet, is capable of exerting sufficient pressure to secure the correct shape required. Necessarily, the working (and setting) temperatures must be kept fairly low in this case and the choice of the suitable resin is likely to be restricted to those thermosetting resins which contain organic acids as accelerators.

Alternatively, the final setting of the resin may be obtained by oven-curing (autoclave) treatment. The aspects of such methods have been described in more detail on these pages.[2]

Continuous Pressure.—The making of circular plywood tubes by a continuous

process is relatively simple when compared with eccentric shapes or oblong-sections with curved corners. The tubes can be built up under contact with a pressure-roller; speed, temperature and the choice of resin are fairly varied though not unlimited. When building up eccentric shapes, the use of a pressure-roller is exceedingly difficult. A system of building up such eccentric shapes on a rotating inner mould has been investigated experimentally[5] by using a balata belt as the external mould. The value of these investigations revealed by Stevens and Turner can hardly be over-estimated. The experiments were carried out by using a Beetle urea resin spread on the veneers.

The question of obtaining the smallest radii in bending plywood can also be approached from the angle of the continuous process. Weldwood (USP, p.f. resin-bonded) plywood hoops of approximately 2¼ ins. are presumably made by building up circular tubes first. As indicated in the paragraph above, the urea treatment of the veneers can, up to a certain point, take the place of the orthodox methods of softening the veneers with hot water, steam, etc., but there is still room for further research by devising methods for bending smaller radii than it is possible with water-soluble urea resin.

Hydraulic pressing.—Hydraulic presses used in large works for veneering curved ground-work can certainly be easily adopted for the production of laminated bodies. As in the manufacture of plywood, the adhesive films will be probably considered more favourably as bonding agents since either hot water, steam, gas or electric heating of the presses is generally available, and plastic films setting at the corresponding temperatures are readily obtained. The use of liquids or pastes of synthetic resins can also be considered, as many of such veneering presses may be fitted with coach springs or other devices necessary to drive out the surplus glue. It is very likely that many of the usual methods of providing the cauls can be readily adopted. By using zinc shapes, for instance, the attainment of temperatures required for the quick setting of urea resin adhesives is certainly practicable.

Although the usual methods and the existing range of synthetic resin adhesives are complementary, and apparently every design can be tackled "somehow" by adjusting and modifying certain conditions of the process, true success lies with the further research. The continuous flow of the operations in the process (and the cycle of output) depends on the skilful combination of the available chemicals and available plant, but there are still many difficulties which can be eliminated only by devising unorthodox methods.

It is too early to tell what part phenol-formaldehyde-rubber resins are going to play in the manufacture of laminated bodies, but the fact that the finished laminated sheets built up with this resin are mouldable[8] may have outstanding consequences on the organizing of manufacturing processes of furniture components.

The question of providing curved shapes with the minimum of time lost in preparing the laminæ is by no means finally solved. There are certain new and revolutionary possibilities of dealing with that problem. It would lead us too far, however, to describe these speculations, ideas and experiments in considerable detail.

"All-plastic" Components

As mentioned above, the stereotyped repetition of the same finished articles and the standardization of the appearance and design is inevitable when compression-moulded plastics are being manufactured, but we have to admit that there are many components of furniture and equipment where repetition and uniformity does not oppose individuality and personality.

Let us only mention one group of such components: trays and drawers, which are important parts of wardrobes, chests

of drawers, desks, etc. We all like these to run smoothly, nevertheless they often get jammed. Even the best cedar-lined drawer collects dust and detritus in the corners. The making of really good wooden drawers depends very much on the skilled assembly of five components (only two sides are similar in the design), even if all the parts are prepared and cut on the various wood-working machines. There is a point where plastics can help a lot.

In Fig. 5 the writer gives a sketch of plastic trays and drawers. These can be made as finished plastic components and half a dozen types would probably satisfy the immediate requirements of domestic, office and hospital furniture.

Naturally it is always wiser to make an allowance for the individual treatment of the only visible surface of the drawer. Fig. 5 shows a possible solution. The front piece of the drawer

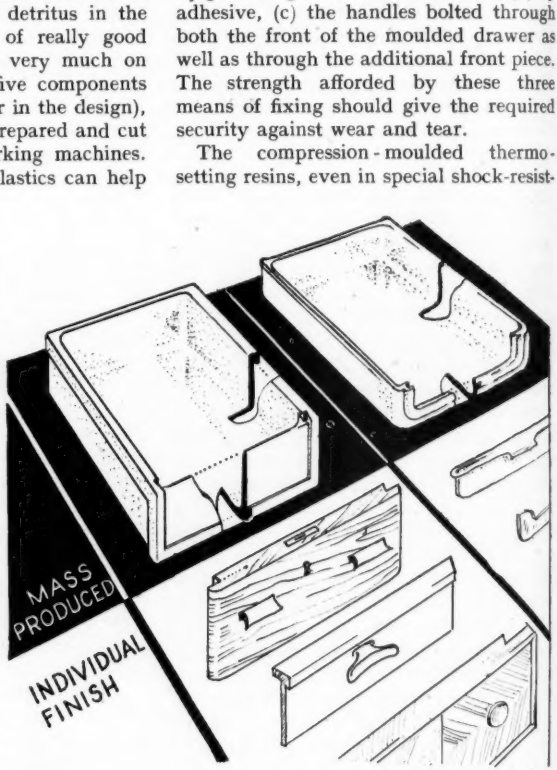

Fig. 5. — A study in moulded drawer-shapes.

may be formed by a combination of materials in order to give the interior decorator a free hand in æsthetic matters.

Such trays and drawers can be made compression-moulded from both thermoplastic and thermosetting resins. It must be remembered that the numbers of replicas run into really high figures. Every household needs a large number of both shallow trays (in fitted wardrobes) which slide on rails and deeper drawers such as used in chests of drawers. The sketched shape would be a type sliding suspended on rails, which may be provided in reinforced or extruded thermoplastic laths. The front pieces, which can be made of wood or plastics, are meant to be secured by a three-fold method: (a) by providing a slot for these fronts, (b) by adhesive, (c) the handles bolted through both the front of the moulded drawer as well as through the additional front piece. The strength afforded by these three means of fixing should give the required security against wear and tear.

The compression-moulded thermosetting resins, even in special shock-resisting type, would probably be still somewhat brittle for providing kitchen drawers. The writer is inclined to suggest that fabric and veneer reinforcement should be incorporated.

The intensive research on this line is inevitable and it is quite likely that we shall have the best results by first building up the shape out of a fibrous and porous sheet, which could be subsequently impregnated with thermosetting resin, and then cured in an oven. The production of transparent injection-moulded thermoplastics is always possible for fancy or display furniture.

The shaping of shallow trays out of

thermoplastic sheets may be practicable for units used in hospitals, offices, etc.

Laminated sheets in which the phenolic resin plus oxidized-rubber mixture is being used, can be, in all probability, moulded to form shallow trays although not quite as "intricate" in design as those shown in Fig. 5.

The Ford method, used in providing wood-filled thermosetting panels in the "plastic-car"[9] is obviously suitable for producing such shapes.

Conclusion

It is clear that the plastics industry is capable of helping the post-war development of furniture in many respects. Let us hope that the clash between the individual requirements of the users and the aim at mass-production on the part of manufacturers will be avoided by devising processes to suit both sides. What makes the questions so involved is that the appearance and design of furniture concerns everybody, and no one is wise enough to be able to dictate the "style" of the furniture of the future. Æsthetic considerations play a large part in determining the manufacturing methods, right down to the assembly of the simplest components.

Meanwhile, it is certainly the plastics technician's job to investigate still further the technical possibilities of improving the general qualities of laminated structures.

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U.S. Army Helmet Liner

THE American soldier now wears two helmets at the same time—one a light helmet made of laminated phenolic resin-impregnated fabric for ordinary field service, and the other the normal steel type which can be quickly slipped on the first for actual combat. "Modern Plastics" for May, 1942, describes in detail this novel adoption. The original form in peace-time was a paper pulp, cloth-covered liner, but it had become obvious to the authorities that a stronger, more serviceable liner could be developed by the use of synthetic resins; moreover, it was apparent that the liner would have to withstand a wide range of temperatures, from −40 degrees F. to over 250 degrees F. (in high temperature cleansing operations). The liner is moulded from 8-oz. duck impregnated with phenol-furfural resin by a simple yet novel process. The female half of the die is a stamped and drawn steel helmet slightly smaller than the standard. The male portion is a heat-resistant bag made of synthetic rubber and lignin capable of inflation within the cavity of the steel helmet.

D

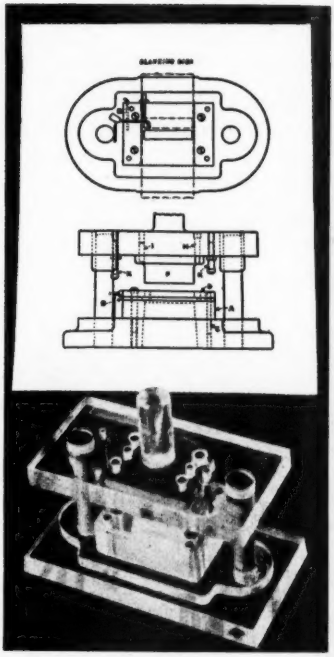
Transparent Models

FOR THE TRAINING OF STUDENTS

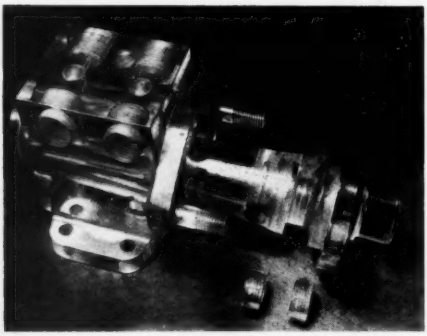
THE number of examples of transparent plastic units made for research work or the training of students grows apace. Clearly we have in this development a new tool for both scientist and educationist of peculiar importance. Its value is being demonstrated at a time when new ideas are being accepted and tested with much greater enthusiasm than in peacetime.

A very recent example that has been brought to our notice is one described in the well-known American journal, " Automotive and Aviation Industries " (April 15, 1942), which mentions that such models of dies, jigs, fixtures, etc., are being extensively used in war training classes established by the U.S. Office of Education. Training time is reduced considerably.

The model shown in the accompanying photograph is made of Plexiglas (the acrylic resin manufactured by Rohm and Haas) and was developed in connection with the Pennsylvania WPA Visual Aid Program. Where it is necessary to show contrast, some parts are made of coloured phenolic resins. The die shown here can be operated in small hand-presses made especially for them. Models of ships and Army warehouses are also being constructed and it is planned to extend the process to courses in aviation and other sections of war production.



Transparent die of Plexiglas used in U.S.A. for war-training purposes.



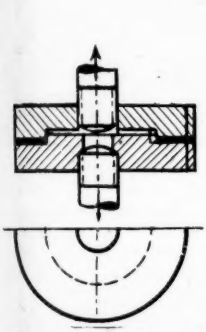
Machined from Catalin cast resin, this Coventry Climax valve model is used for demonstration purposes.

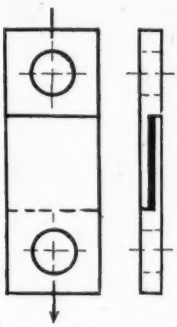
The application of transparent plastics to the production of ship models and warehouses is most interesting and has not been developed at all in this country. Presumably, however, they will not be of cast resin but of transparent sheet.

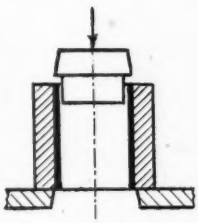
The most recent of British examples is one just received from Coventry Climax Engines, Ltd. Readers may remember that this concern wrote us inquiring the possibilities of making transparent instructional models of their patent coupled cooling valve fitted to all " Godiva " Trailer fire fighters. The machined Catalin model shown in the photograph (left) is the result and we understand it has proved its value in demonstrations.

Heavy-duty Bearings in Plastics

Design and Operating Characteristics of a New Type of Plastic-lined Bearing are Described







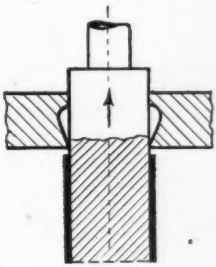


Fig. 1 (above, left).—Ringplate with plastic disc giving 7.8 sq. in. of adhering surface. Fig. 2 (above, right).—Shear plate with plastic film in shear (3.9 sq. in. adhering surface). Fig. 3 (right).—Bush with internal plastic shell corresponding to ordinary bearing principle, giving adhesion area of 10.8 sq. in. Fig. 4 (extreme right).—Shaft with plastic sleeve (10.8 sq. in. adhesion area), cemented and cured.

EXPERIENCE and research have, hitherto, tended to indicate that plastic bearings are not suitable for applications involving high mechanical stress, or for those entailing, for other reasons, the development of large quantities of heat which must be rapidly dissipated in order to avoid the generation of high temperature.

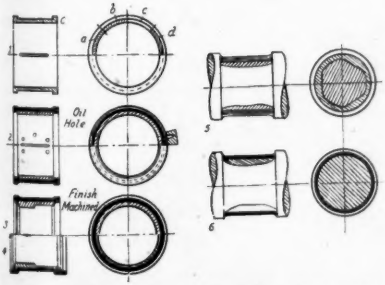
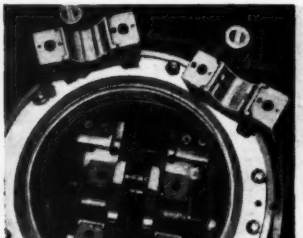


Fig. 5.—Different forms of test bearings used. Direction of laminations:—Parallel to working surface, *a*; right angles to working surface, *b*; parallel to end face, *c*; wound type, *d*.

Already, some years ago, it had been suggested that one way of improving the behaviour of plastics as bearing materials would consist in "inverting" the usual design by providing the shaft with a relatively thin plastic shell, which, in turn, would run in a steel bearing.

Priority for this suggestion is claimed by numerous parties. Principal credit, it would seem, must go to Professor Heidebroek (Technical University, Dresden; Roemmler-werke), and Gilbert of the Deutsche Versuchsanstalt für Luftfahrt, who, independently registered designs for this device.

In its initial stages, a bearing of this type appeared to possess serious technical drawbacks. Nevertheless, Gilbert, in



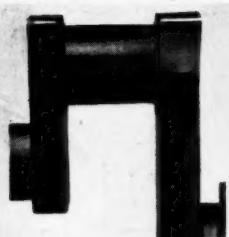


Fig. 6 (left).—Crankcase of a single-cylinder engine with externally wound plastic bearings after 120 service hours. Maximum load 1,820 lb./sq. in.; rubbing speed 2,200 ft./min.; 3,000 r.p.m. Fig. 7 (centre).—Part of crankshaft of "Wanderer" engine after 7,500 miles' service (wear 0.05-0.1 per cent. dia.) Fig. 8 (right).—Plastic-film-wound wheel bearing on large aeroplane.

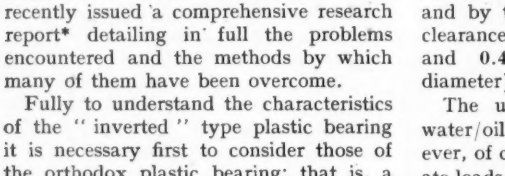
collaboration with Leurenbaum, has recently issued a comprehensive research report* detailing in full the problems encountered and the methods by which many of them have been overcome.

Fully to understand the characteristics of the " inverted " type plastic bearing it is necessary first to consider those of the orthodox plastic bearing; that is, a steel surface rotating in contact with a plastic surface. In general, this type of bearing was adopted for purposes demanding the fulfilment of no very arduous conditions. Difficulties caused by temperature increase, such as, expansion of the plastic mass and accumulation of heat due to the low thermal conductivity of the material, as well as swelling under the application of lubricants, were improved by increased heat transfer consequent upon the use of larger quantities of lubricant circulating at higher speed, and by the provision of relatively large clearances (amounting to between 0.3 and 0.4 per cent. of the bearing diameter).

The usual lubricants are water and water/oil emulsions, which permit, however, of continuous running under moderate loads only, permissible pressures being in the range 650-850 lb. sq. in. Only where bearing segments of considerable thickness were used, thus permitting the strengthening of the plastic by means of metal inserts, was it possible to cater for higher specific loads; roll-neck bearings are a case in point.

According to the new arrangement, resin-impregnated textile bands are wound around the shaft; several thin layers up to 0.008 in. thickness are moulded under pressure around the shaft, to which they are caused to adhere.

* "V.D.I." Zeitschrift, 1942/86/139.



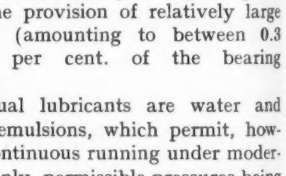


Fig. 9 (above).—Lower crankshaft of a Junkers 205 C. engine with externally wound bearings after 210 service hours. Fig. 10 (right).—Part of the crankshaft in Fig. 9. The grooves at the crankshaft bearing were caused by impurities in the oil during the running-in period.

The wound layer is then cured in the ordinary way. This device seems to be particularly suitable for crankshaft bearings of lighter type internal-combustion engines.

In Table I are presented the results of earlier investigations on bearings of this type in a bearing-testing machine. Comparison is made with bearings of the orthodox type in plastics and with some metal bearing materials. Capacity for increased loading of the new type plastic bearing is amply demonstrated. Whereas bearing brasses can carry continual loads up to only ± 150 kg. sq. cm., 2,100 lb./sq. in. if large clearances be employed, loading capacity with the new bearings reaches 250 kg./sq. cm. (3,500 lb./sq. in.) for continuous runs. With intermittent runs, or for short running periods, and for running speeds up to 2,200 ft./min., specific loads of ± 300 kg./sq. cm. (4,500 lb./sq. in.) are possible, usual conditions as to lubrication being presupposed.

Metals and Plastics Compared

Thus the superiority of the new type plastic bearing over tin-base and lead-base alloys is established. The new materials, however, do not reach the values obtained by high-grade bearing bronzes. Practical trials were made with crankshaft bearings in aircraft and motor-car engines; these two applications make most stringent demands in bearing quality and strength, as, due to restricted working space, the thermal environment is very unfavourable.

Analogous to tape-winding, a less expensive method consists in covering the shaft with plastic foils in various stages of curing, according to production requirements. As in the case of the impregnated tapes, however, the foils must be bonded to the metal surfaces. A final finishing operation is only required if extreme accuracy be necessary, for the foils themselves can be produced to limits of ± 0.004 in.; only the joint may cause some difficulty. Particularly for tight-fitting bearings, such as aeroplane propeller hubs (where high variable loading and, in consequence, variable repeated elastic deformation, increases the tendency to fretting corrosion), foil-type bearing surfaces have proved highly satisfactory.

Other uses are for the bearing surfaces on the telescopic structures of retractible under-carriages, in pumps, and for thread bushes. Indeed, as compared with metal-to-metal fittings definite technical advantages have been demonstrated.

The usual tests for plastic bearing materials are hardly sufficient to cover the requirements for a plastic/steel complex such as is dealt with here. It will be recalled that the plastic itself is only 0.2-1 mm. in thickness and is integral with the steel body of the shaft.

Test results will now be described as obtained for a hemp-fabric-wound bearing with a resin content of 43 per cent. After moulding, curing was effected by heating for 150 hours in an oil bath at 100 degrees C. The tensile strength on a special sample 230 x 20 x 25 mm. (in the direction of lamination) ranged between 12.6 and 13.8 kg./sq. cm. Elongation was 2 per cent. Suspended for six days in lubricating oil at 20 degrees C. absorption amounted to 0.2-0.3 per cent. by weight. In leaded petroleum at 20 degrees C. absorption amounted to 0.2-1.3 per cent. by weight; in glycol at 20 degrees C. absorption amounted to 0.8-1.6 per cent. by weight. In oil or air, impregnated bearing material can be heated to 135 degrees C. before discoloration due to decomposition commenced.

Factors Controlling Adhesion

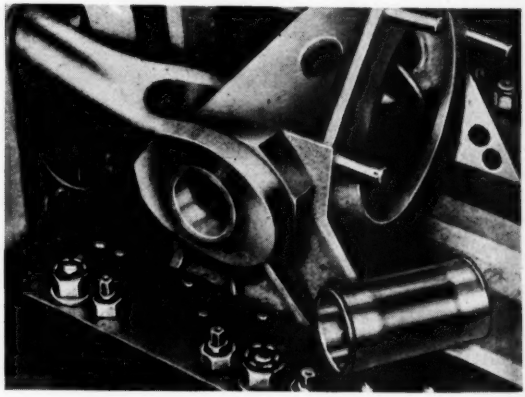
In the case of plastic foil wound around a steel shaft, binding strength between foil and the steel increases with increase of resin content from 40 to 50 per cent. When the foil is wound inside bushes, resin content appears to have little effect on binding strength. The shear strength of the material is also little affected, for resin contents vary between the limits stated.

The author's report points out that these values are purely relative. Under experimental conditions it was found diffi-

cult to obtain uniform binding of the foil and impregnated tape on to the shaft, hence the prestressing of the plastic coating clearly varied. In general, the appearance of the fracture of the binding indicated the quality of the latter.

Shrinking and swelling of the binding during curing were measured on special samples 40-41 mm. dia. built up to bindings about 2 mm. thickness. Where curing was undertaken in an oil bath, shrinkage continued for curing periods of up to 200 hours, hence it is concluded that this

Fig. 11 (above).—Starting-carriage bearing with plastic thrust rings. Fig. 12 (right).—Wound crank bearing of crosshead of test machine.



represents the minimum period for obtaining material in the fully cured state. After 150 hours, however, linear shrinkage was in the range of only 0.3 per cent. of the winding thickness and hence may in most cases be ignored. Suspension of the cured bearing in heated grease resulted in swelling to the extent of 0.3 per cent. of the winding thickness; continued suspension in this medium showed no further swelling to take place.

Curing treatment in hot grease caused shrinkage of 0.6-1 per cent. of winding thickness, constant value being reached after 300 hours. Again, in this case, after curing for 150 hours, additional treatment causes linear variations of the order of 0.5 per cent. Even with curing times of 200 hours, suspension of the samples in hot water and cold water caused swelling amounting to about 8 per cent. of the winding thickness to occur. Further research is being undertaken on improved methods of impregnation in order to eliminate swelling.

The use of cemented linings or windings shows considerable advantages as compared with ordinary bushings, as the thicknesses of the winding need only be in the order of 0.5 to 1 per cent. of the diameter, and can within reason be selected at will.

Bearing clearances of 0.09-.12 per cent. of the bearing diameter are ample for bearings running at elevated temperature if the oil or grease lubricant employed possess reasonably good heat conductivity. This corresponds to practice adopted with metal bearings and favours the production of an oil film of good hydrodynamic properties.

So far, no really satisfactory method has been found for testing the adhesion between the plastic winding and the metal base. Electric and X-ray methods have not proved successful, but an acoustic method of some promise is being investigated. To some extent, observation of the note obtained on tapping the bearing with a small metal hammer has enabled satisfactory conclusions to be drawn as to the state of adhesion between the two parts of the complex. With some training, an operative can determine faults in adhesion.

Wear in the plastic bearings described is in general equal to that occurring with tin-base and lead-base alloys, although in individual laboratory tests it proved to be higher (double these values). Wear depends not only upon load and lubricating conditions, but also on the surface quality of the sliding faces. Plastic bearings of the usual type commonly require ground and polished shafts of hardened steel; for wound bearings of the type described, however, plain carbon steels, unhardened, with a tensile strength of about 38 tons/sq. in. have proved quite suitable.

No Scoring of Shaft

It was found that, after prolonged running, when the oil used had become extremely dirty, no scoring of the shaft occurred. Commencing with clean lubricating oil, wear values obtained in the bearing testing machine for a running period of 200 hours, specific pressures up to 3,500 lb./sq. in., rubbing speed 1,900 ft./min., and for bearings of 40-80 mm. dia. were, for the wound plastic bearings, 0.06-0.1 per cent. on bearing diameter, the steel shell in which the plastic sleeve ran, wearing at the same time to the extent of 0.01-0.02 per cent. of diameter.

In actual practice, the bearings on engines in motorcars and for general engineering purposes may be expected to show higher wear according to running conditions, and impurities or breakdown products occurring or arising in the oil. For instance, in one case, after 200 hours of running, wear of the plastic film was found to amount to 0.1-0.15 per cent. dia., whilst that of the carbon-steel bearing in which the shaft was running amounted to 0.05-0.1 per cent. dia. Where a cast-iron bearing was used with the same plastic-wound shaft, wearing amounted to 0.02 per cent. dia. Cast magnesium alloys gave a wear of 0.3-0.4 per cent. dia., a value much too high to be satisfactory.

As steel bearing surfaces under these conditions did not show wear exceeding 0.2 per cent. dia., it would seem that bearings of this type could be used in aircraft engines where frequent overhaul is practised. For motorcars, however, where overhauling is much less frequent, it would seem that these wear figures are too high.

For low specific pressures in the range of 700-1,400 lb./sq. in. and rubbing speeds up to 950 ft./min. wear is low, and where sufficient lubrication is employed the wound plastic bearing compares very favourably with the usual metal bearing.

It is well known that the low heat conductivity of plastics (in the order of 1.0-0.5 per cent. of that of metals) may cause difficulty, and, in the case of bearings of orthodox design, prevents the use of plastics for automobile engines, subject to great variations in running speed and load. Bearings with the "wound design" are capable of withstanding such variations which may occur when starting up motorcar engines, or when bringing aircraft engines rapidly from idling speed to full speed under load.

Results of comparative bench tests between a cast-iron shaft running in a leaded-bronze bearing and a steel shaft provided with thin plastic sleeve running in a steel bearing are interesting. Loads were varied between 0. ± 2,100 lb./sq. in. and running speeds between 500 and 1,600 ft./min.; other conditions were equal in both cases. Thermal measurements showed the new wound bearings reached a higher temperature than the ordinary metal bearings when operating at maximum load and speed, temperatures obtained being about 20 degrees C. Heat transference through the plastic film to the shaft did not appear to occur.

Need for Ample Oil Cooling

However, trial running with light engines showed that with oil circulating at the rate of about 20 litres/hour over each bearing, excessive accumulation of heat was prevented by dissipation through the lubricant itself and through the metal bearing.

In small engine units insufficient supply of lubricant causes difficulties, and overheating of the bearing is very likely to occur. In aircraft engines, on the other

Table 1.—Comparative Tests on Plastic Bearings and Metal Bearings.

Bearing type	Filler material	Brinell hardness, 2.5/15.6/180		Clearance when fitted, mm.	Maximum load after running in ±kg./cm.²	Rubbing speed		Highest bearing temperature, deg. C.	Service life		Wear,* mm.	Reason for interruption of trial
		At 20°C.	At 100°C.			Maximum, m./s.	At maximum load, m./s.		Total hours	Under maximum load hours		
1a	Paper	32	29	0.150	40	5.5	5	80	22	3	0.01	Fracture in direction of laminations
3c	Paper	32	29	0.164	48	8.5	5 to 8	115	38	27	0.095	Loosening of inserts
2c	Paper	32	29	0.153	68	11.0	6 to 7	80	53	11	—	Fracture in direction of laminations
1e	Paper	29	18	0.132	50	8.6	3.9 to 8.6	100	13	4	—	Deformation of brasses
3e	Paper	29	18	0.125	50	8.6	5.5 to 7	130	41	11	0.034	Bearing burned
1b	Linen	32/36	32/40	0.146	90	12	5.6	90	42	2	—	Bearing broken
2c	Linen	32/36	32/40	0.125	93	9.5	4.3	120	79	2	—	Fracture in direction of laminations
3d	Linen	21	8/13	0.098	100	11.0	4	100	52	2	0.25	Fracture in direction of winding
3c	Linen	32/36	32/40	0.132	50	7.9	3 to 7.9	120	34	10	0.08	Bearing broken
1d	Asbestos	24/26	22/31	0.072	90	8.0	8.0	110	98	22	0.18	Fracture in direction of winding
3d	Asbestos	24/26	22/31	0.108	150	9.0	9.0	80	181	85	0.09	Excessive increase in clearance
4d	Asbestos	24/26	22/31	0.123	140	11.7	3.9	120	40	4	0.135	Bearing started to break. Excessive increase in clearance
5d	Asbestos	23/28	23	0.051	60	8.0	8.0	125	45	17	0.13	Winding loose
5d	Hemp linen	13	13	0.081	45	8.0	3.2 to 6.4	120	12	5	—	Winding loose and fracture at the edges
6d	Glass wool	—	—	0.088	150	8.4	3 to 4	130	105	16	0.104	Running surface broken
6d	Asbestos	32	29	0.120	185	8	8	100	98	17	0.083	Running surface broken
6d	Hemp linen	20	14	0.100	165	9	8	80	440	160	0.08	Running surface broken
6d	Hemp linen	—	—	0.074	240	11	11	100	285	22	0.061	Running surface slightly damaged at edges, otherwise in good condition
6d	Hemp linen	—	—	0.039	200	7.4	12.5	140	373	258	0.08	Bearing temperature too high
6d	Hemp linen	—	—	0.067	300	7.7	4.9	90	76	5	—	Faults in winding
6d	Hemp linen	—	—	0.084	325	7.7	7.7	120	90	21	0.027	Running surface damaged
Lead-base alloy ..		15.9	7	0.08	185	5	4	100	126	30	0.02	Bearing broken
Tin-base alloy (80% tin) ..		27	11.5	0.03	190	15.3	5 to 13	130	196	120	0.025	Bearing partly broken
Cadmium-bearing..		—	—	0.092	200	12.4	12.4	100	420	380	0.011	Running surface several times broken and shifted

* Bearing diameter between 69–72 mm. (2⅞–2⅞ in.).

hand, in which the volume of oil circulation is 10-20 times (by volume) that commonly used in the small car engine, and where oil coolers were provided, the average temperature of the new bearing proved to be the same as, or merely slightly higher than, that of the metal bearing of ordinary design.

Where grease lubrication was employed thermal analysis could not be made, but service tests on axle shafts of aircraft undercarriages showed that thermal equilibrium was reached, invariably, at temperatures much below 100 degrees C.

The thinness of the wound plastic layer in bearings of the new design enables bearing clearances to be selected independently of the thermal expansivity of the plastic material itself, which may amount to between $15 \times 10^{-4} \times 25 \cdot 4$, in extreme cases it may be double that of metals.

The difference in diameter of a steel shaft with and without an applied wound layer of plastic 1 mm. in thickness for a temperature increase of 100 degrees C. is only 0.003-0.005 mm.; for still smaller thicknesses of wound plastic film and greater bearing diameters, the diametral increase is practically negligible.

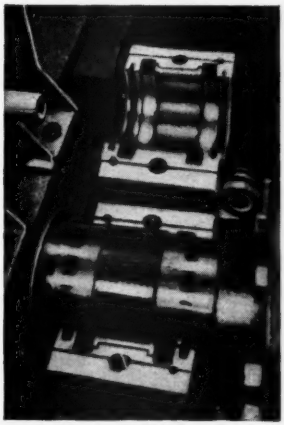


Fig. 13.—Oscillating pivot embedded in plastic material. Endurance testing machine, pressure oil lubrication.

After prolonged bench tests, the new bearings were installed for trial purposes in a single-cylinder engine. For various resin-impregnated bases, such as cellulose fibre, rayon, glass-wool and hemp, the range in loading capacity and wear resistance experienced was the same as that determined on the bearing testing machine.

A four-cylinder Argus A8, 135 h.p. aircraft engine running at 2,200 r.p.m. was then employed to test the new bearings under continuous, full-load conditions. Crankpins and main crankshaft bearings were wound with plastic films 0.09 mm. thick and were arranged to run in bearings of a 38-ton carbon steel. Bearing clearances of an average value of 0.14 per cent. dia. were provided, total oil circulation was 620 litres per hour, giving each bearing about 40 litres per hour.

When the test run had to be interrupted owing to general wear of the engine after 132 hours, the bearings themselves were still in perfect condition. For a specific bearing pressure of 1,680 lb./sq. in. and a rubbing speed of 1,300 ft./min., crankpin wear was only 0.05 mm. and crankshaft main-bearing wear 0.057 mm., i.e., 0.09 per cent. dia.

The new bearings were then tested out in a modern heavy-duty engine—a Jumo 205C of 600 h.p. running at 2,200 r.p.m., entailing maximum specific pressures of 3,640 lb./sq. in. In the total run of 230 hours, the engine was, for about 170 hours, subjected to 85 per cent. load at a speed of 2,100-2,200 r.p.m. At the conclusion of the test all bearings were found in a satisfactory state, exhibiting only minor scratching due to foreign matter in the oil.

Further trials were made with the new bearings in motorcar engines. Here variable results were obtained. A 30 h.p. "Wanderer" engine was equipped with plastic bearings for the crankshaft, and, after running in for 1,250 miles, was used under full load conditions on town and main motor highways. Lubrication was by means of reclaimed oil.

After 7,500 miles, i.e., a service period of about 200 hours at an average speed of 37.5 m.p.h., the engine was dismantled; bearings and the wound plastic sleeves on the shafts were in perfectly satisfactory condition. Wear of plastic and steel

* Bearing diameter between 69-72 mm. (2⅝-2¾ in.).

together was only between 0.02 and 0.45 mm., i.e., 0.05-0.1 per cent. dia., and this in spite of the fact that excessive foreign matter in the oil might have proved very harmful. Average bearing temperature was about 100 degrees C. Overheating did not occur under conditions of most violent acceleration and under continual load. The total weight of oil circulating was in this case only 17.2 lb.

Crankshaft bearings on two Opel Olympia engines of 1.5 litres and 1.3 litres cylinder capacity as well as on a Ford-Eifel car are still being investigated.

Unsatisfactory results were obtained in trial bearings in a four-cylinder engine for military use, the trouble being attributed to unsatisfactory adhesion of the wound plastic layer to the metal base. In nearly every case where bench or service tests gave unsatisfactory results, excessive overheating had occurred, and this could usually be traced to too low an oil circulation in individual bearings. Special tests are being undertaken to clear up difficulties of this nature.

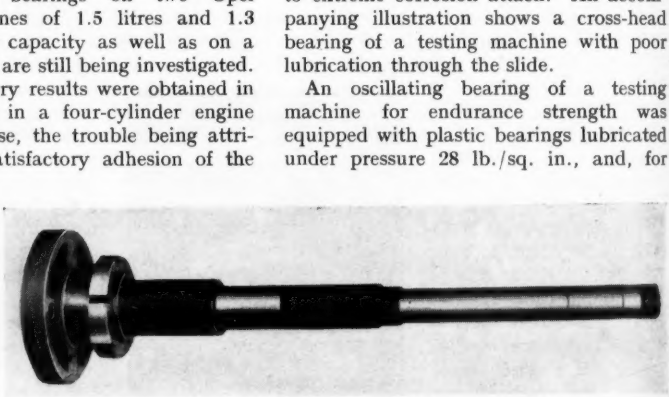


Fig. 14.—Lathe head spindle with wound bearings after 1,000 service hours. Load about 280 lb./sq. in., rubbing speed 720 feet/min.

Apart from i.c. engines, the new wound plastic bearings have already been put to test on aircraft undercarriages as substitutes for bronze bearings. In 10 sports aeroplanes and on two large aircraft, thin steel bushes with externally wound plastic foil surfaces were pressed on to the axle shafts, and were running in 38-ton carbon steel bearings pressed into the wheel hubs. These tests are still in progress, but some of the bearings have already undergone more than 3,500 starts in training service for a wear of 0.1-0.15 per cent. dia. One machine has been started up more than 5,200 times. Results to date are so favourable that it seems possible that a total life of 500 starts may be assumed before overhaul becomes necessary.

The value of the new type plastic bearing was also demonstrated in applications where bearings are performing small angular oscillations under reliable conditions of high pressure.* It has been found that they could be used in environments where ball and needle bearings fail owing to extreme corrosion attack. An accompanying illustration shows a cross-head bearing of a testing machine with poor lubrication through the slide.

An oscillating bearing of a testing machine for endurance strength was equipped with plastic bearings lubricated under pressure 28 lb./sq. in., and, for 100 million stress reversals, wear was only 0.01-0.02 mm. for a bearing diameter of 115 mm. It is intended to use bushings of porous sintered metal to allow more uniform lubrication.

The first application of the wound plastic bearing in a machine tool has shown that not only can difficulties of overheating be entirely avoided but also that lower wear figures as compared with conventional metal bearings are possible. Bearings of this type need overhauling, so experience shows, only about once every three years, and this can be carried out in such a way that the wound plastic is reground and the steel bush readjusted.

At the present time the wound plastic bearings are, in practice, running in nitrided steel bearings, but the present research demonstrated that it may be possible to use plain carbon steels and cast iron.

* "V.D.I. Zeitschrift," 1942/86/144.

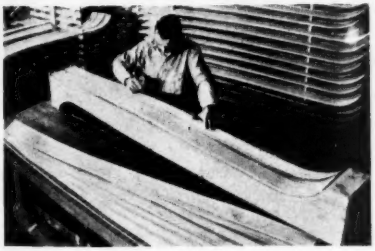
IDEAS——

By the Editor

Resin-bonded Skis

A recent issue of " Durez Plastic News " contains the item that skis for the American ski-troops working in the Far North are being made of resin-bonded laminated veneers. It is claimed that they give longer life and are stronger than the old type, since the resin waterproofs and weatherproofs the skis. Moreover, in service it has been found that while these skis are given the usual waxing treatment it has not been necessary to seal them or hold them in shaping clamps when not in use.

What is also interesting is the fact that these skis are being produced by the Allied Aviation Corporation of Baltimore, using the Vidal process, already well known as a method of producing the so-called " plastic " aeroplane. The impregnated cut veneers are

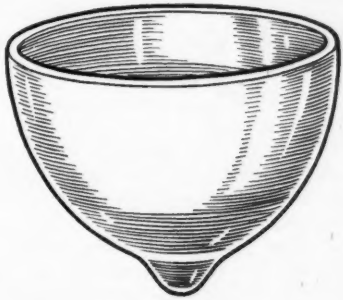


placed on a wooden former, covered with a rubber blanket and wheeled into a pressure tank for final curing.

Rubber Latex Cups

While the loss of our Malayan sources of rubber is a major disaster, there is a bit of consoling news in the fact that some production of rubber is being carried out in Africa and elsewhere. While this must be small, relative to our total needs, it is not tiny, and is growing steadily. Some idea of the size of the plantations of a small company can be gauged by the fact that latex cups for catching the rubber from the trees are ordered in lots of 10,000 or so. This brings me to the point raised by a member of a Uganda rubber company, who told me of the difficulty of obtaining the metal (aluminium) or glass latex cups. I should think that here is an ideal outlet for moulded plastics.

Almost any plastic would be quite suitable for the job; the cups receive a good deal of



knocking about, so they should be of a fair thickness. The cups vary in size, apparently from 5-10 oz. latex content; that is, from 8.5 to 17 cubic ins. It seems strange that some of the cups used should be of glass, although this may be for transparency.

The example shown in the drawing, given to me by the aforesaid individual, is half-lemon in shape. The curious excrescence in the bottom appears unnecessary, although there is probably a good reason for it.

LETTER TO THE EDITOR

Extrusion Machines

When reading my paper on " Plant for Injection Moulding, Die-casting and Extrusion " at the Midlands Section of the I.P.I. (reported in Vol. X, No. 16, June, 1942, of " Transactions "), I omitted to mention that the process and apparatus referred to on pages 30-32 for extruding thermosetting resinous materials are the subject of various letters patent and patent applications, all of which are controlled by Messrs. F. A. Hughes and Co., Ltd., Abbey House, Baker Street, London, N.W.1, to whom any application for licence should be made.

J. L. DANIELS.

Stroud.

World's Industry Employs Plastics

ELECTRICAL

Screw connections in plastic components may with advantage be avoided in electrical switches and switchgear. The screw method employs a contact bolt of threaded square brass, carrying at its upper end a nut for tightening down on the resin baseplate, and also for holding the connecting pieces. This design is both expensive and complicated, and attempts were made to replace it by one or more of the following devices. In place of the square brass rod, flat pieces of brass or of steel were taken and moulded direct into the baseplate; although simple in theory, this system caused considerable trouble and was abandoned. Eventually, close collaboration between moulding expert and designer evolved a solution, so that moulding pins of small diameter and as rigid as possible were employed. Details of this successful plate device are given in "Technische Rundschau," March, 1942. **Taping of stator coils,** commonly carried out with cotton, may be done equally effectively with cellulose fibre. **Heat-resisting insulation,** which hitherto has rendered necessary the use of asbestos and/or mica, is simplified by the use of glass fibre, which, woven into tape, is highly flexible and can, if required, be treated directly with insulating lacquers. **Cable exposed to acid fumes or oil vapours** is insulated preferably with synthetic rubber rather than natural rubber. It is interesting to note that certain newer types of cable employing the synthetics as insulating materials need less protection by additional taping, etc., against mechanical damage and wear; thus the assembly can be made smoother, this facilitating drawing through conduit and conferring the additional advantage of providing a surface less favourable for trapping of moisture drops. Deterioration caused by the action of fungoid growths, etc., is entirely absent. Special cable employed for the transmission of broad frequency bands in television employ Styroflex (German polystyrene) as insulator.

GENERAL ENGINEERING

Bearings for shafts of diameters between 1.5 and 6 mm. may be constructed of textile-base laminated sheet, according to a report in "Technische Rundschau," January 13, 1942. A suitable quality shows two layers of fabric per mm. thickness. The account points out that, as opposed to paper-base material, the fabric-base permits of higher resin content, which renders the bearing less sensitive to high humidity and against actual water. Thermal expansivity lies between 10×10^{-6} and 25×10^{-6}, these figures permitting not only the manufacture of bushes, but also the construction of complete instrument end plates without risk of distortion causing change of centre distances. Pressed-in bushes must be given greater limits than metal bushes. They should also be soaked for half an hour at 90 degrees C. in hot transformer oil before being pressed in. It is pointed out that heat-dissipating power of plastic bearings is low; hence, for high-speed bearings fits should be carefully chosen. The account tabulates bearing and shaft limits. Endurance tests have shown these bearings both reliable and

hard wearing. Gears running eight hours per day showed, after a total of 600 hours' service, an increase in bearing clearance of only 0.01 mm., this figure including running-in wear. Good lubrication is essential. **Patterns for casting shops** are, according to "Giesserei," 1942/29/117, successfully produced in resin-bonded laminated paper. Patterns in this material are more suitable for large production than those in wood, and enable the use of cast-iron or light-alloy patterns and wooden patterns reinforced with metal to be dispensed with. For big surfaces, dimensional stability of the laminated paper is particularly advantageous, whilst, for thin-walled patterns, laminated paper enables the use of metal sheet to be dispensed with. The life of such patterns is stated to be considerably longer than those made of wood.

MOTORS

Light alloy pistons frequently cause trouble during the running-in period, hence the development of systems for coating them with soft metal, such as tin and lead; plastic preparations seem to be equally successful for the purpose. Running-in was, in fact, reduced, whilst the plastic coating appeared to afford considerable protection to the piston skirt against corrosive attack during cold start. The plastic layer withstood temporary overheating, whilst worn-off particles appeared to cause no damage. Further details may be found in V.D.I. Zeitschrift, 1942/86/245, general discussion on the theory of piston coating practice being contained in "Light Metals," 1942/5/317. **Worm-wheel rims** may, according to Altmann (V.D.I. Zeitschrift, 1941/85/8), be successfully produced in a phenolic resin. Such wheels are capable of resisting rubbing speeds up to 900 ft./min. and a specific load of 3,500 lb./sq. in. These values, incidentally, are about one third of those for bronze and half of those for aluminium-base, magnesium-base and zinc-base alloys.

TEXTILES

Flax waste is said to be the basis of a new textile fibre, known as Cotinin, which has recently been noted in the Danish Press. It is particularly recommended for use in conjunction with cellulose wool, its mechanical properties exceeding those of this material, particularly in the wet state. Danish textile manufacturers are said to be considering the wide-scale exploitation of this material. Production, it appears, is to be taken over by a subsidiary of the A/S de Danske Bomuldspinderier in Je Velje. **A new synthetic fibre known as Perlon** is said to be superior to the earlier type of p.c. fibre, although resembling it chemically. Improved elasticity and tensile strength are claimed. In general, mechanical properties are said to be superior to those of natural silk.

MISCELLANEOUS

Application, forming and machining of polyvinyl chloride are exhaustively discussed in a recent issue of "Technische Rundschau." The account points out that materials on this base are available in tube, sheet and foil form. Tubes may be manufactured to withstand a nominal pressure of 84 lb./sq. in. at temperatures up to 400 degrees C. At temperatures between 40-60 degrees C. working pressure must be considerably reduced. Precise working conditions govern limiting pressure and temperature ranges. At temperatures below 40 degrees C. the tubes may be freely suspended at intervals to 3-5 ft.

For temperatures above 40 degrees C. tubes must be placed on suitable supports or may be carried in metal tubes. Application of external stresses to the tube should be avoided; clamps should be of loose fit, whilst the weight of valves should not be borne by the tubes. Thermal expansivity of polyvinyl chloride is about seven times that of steel, hence long lengths should be provided with adequate expansion joints. Sheet polyvinyl chloride may be machined in a manner similar to the light metals and is readily sawn, turned, cut, punched, drilled, milled and planed. It may be bent, seamed and pressed and joined by cementing or welding. Sawing is best performed with metal hacksaws with a drawing cut; for larger work, circular or bandsaws may be used. Providing the work be not too big, vibratory saws may satisfactorily be employed. In all machining, development of excessive heat is to be avoided as the chips soften; clogging of the tool then results and either the job or the tool itself may be spoilt. Sheet up to 0.08 in. may be cut with shears. Clearance should be at a minimum, and cutting speeds should be uniform or jamming may occur. Machine-driven paper shears are useful for mass-production work. The thread cutting and tapping present no difficulty. When turning cutting speeds and tool forms should correspond to those used in the machining of light alloys. To avoid development of excessive heat, high cutting speeds, small cutting depth and very sharp tools should be used. Interrupted cuts must, as far as possible, be avoided. Punching of foils and plates may be carried out with knife-edge punches or with ordinary punches and matrices. The knife should be pressed slowly into the foil or sheet. Embossing is carried out with punches heated to 60-70 degrees C. Drilling and milling demand the use of cutting speeds as recommended for light alloys, compressed air being blown directly on to the cutting edge of the tool to avoid accumulation of heat. **Cementing of polyvinyl chloride** to itself or to metallic or other non-metallic surfaces is covered by several well-developed techniques which employ either solvent-containing or solvent-free adhesives. A point of interest lies in the fact that the surfaces to be joined must be carefully degreased before application of any cement, and for this purpose methylene chloride is suggested. Tube bending requires the heating of the material to about 130 degrees C. Hot-air blast, batswing flame or hot oil is suggested as a suitable means of heating. The tube itself is filled with sand to avoid flattening, and care should be taken to avoid bending at too low a temperature. In general, correct temperature is indicated by the tube sagging under its own weight. **The position of hard rubber** in plastics technology is considered in a publication of the Joseph Stokes Rubber Co., Trenton, New Jersey. It is considered as intermediary between thermosetting and thermoplastic compounds; its general behaviour being that of a thermosetting material, although it softens under the action of heat. Composition, moulding, blown goods, rod and tubing, sheet production and working, machining, colouring and cost factors are dealt with. Particular attention is paid to the design of moulds for hard rubber and paints for their surface treatment. Of considerable importance is a tabular comparison of the properties of hard rubber with those of wood-filled phenol-formaldehyde resin, cellulose acetate, urea-formaldehyde, polystyrene and polyvinyl chloride. According to the figures given, hard rubber compares favourably with the newer resins. **Black sheet as an alternative to tin-plate** for the manufacture of containers is receiving wide consideration. Weise, in a recent issue of " Korrosion und Metallschutz," discusses the problem of food canning in this material and considers the merits of plastics of various types as surface-protection media for the metal base. High flexibility and elasticity, low solubility and absence of toxic properties are primary requirements. Porosity in the coating must be entirely absent. Weise notes that highly acid fruit juices and vinegar, amongst others, cannot yet be packed in black sheet.

Shellac and the Plastics Industry

Although one of the oldest and most important of naturally occurring plastics, shellac has been the subject of extensive research to make it more amenable to compression and injection moulding

As a corollary to our notes on the injection moulding of shellac published in the July issue of "Plastics," it is interesting to read the most recent brochure published by the Indian Lac Research Institute, entitled "Practical Applications of Recent Lac Research," edited by H. K. Sen, with special reference to shellac plastics.

While, as has been mentioned already in these pages, many of the properties of shellac and of the mouldings made from it are less attractive to moulding manufacturers and users than those of the better-known plastics, yet it seems likely that a wider use will be made of them even outside India. Obviously the main attraction of shellac plastics to Indian manufacturers and the Indian market is the relative cheapness of the raw material compared with the price of imported plastics even during peace-time, the fact that in war-time imports are cut down to a minimum and, perhaps above all, the admirable tendency to exploit to the full the natural resources of the country. Furthermore, the excellent insulating properties of shellac make it the possible starting point of valuable electrical insulating materials.

Almost the only method of moulding shellac hitherto employed is the well-known one of cold moulding, which is almost universally adopted for the manufacture of gramophone records—a method for which it is ideally suited. On the other hand this process is a much slower one than the heat-pressure technique of phenolic and urea moulding so that modern shellac moulding research has leaned towards the formulating of shellac compositions which would make them amenable to moulding in hot moulds. At the same time it has been realized that they should be more heat-resisting than gramophone-record compositions.

The present brochure describes the research done towards this end and the point reached in producing shellac composition mouldings both for hot compression and injection moulding.

Hot-compression Moulding

The melting point of shellac can be raised by several methods, heat-treatment, acid and urea reaction, but all resulting products must be cooled before ejection from the mould. Shellac treated with formaldehyde and urea result in a compound that can be ejected from a hot mould.

1. Shellac-Urea Plastics

The procedure of manufacture is as follows:—Shellac, formaldehyde, wood flour, calcium stearate, pigment and rectified spirit are digested in a steam-jacketed still for some hours, the alcohol being distilled and recovered and the pasty mass remaining in the still is withdrawn and kneaded in a vacuum mixer. The dried residue is ground to 60 mesh in a disintegrator. The powder is finally dried at 95 degrees C. until the batch shows free-flowing properties, and is non-blistering when moulded at 120-150 degrees C. and ½ to 2 minutes in the press. The articles thus made can be polished, if necessary, on a buffing wheel or sprayed with lacquer to improve their appearance.

The heat and water resistance of the moulded products can be greatly improved by baking them for several hours at 60 degrees C. and then gradually increasing the temperature to about 120 degrees C.

An interesting addition to already published information on shellac plastics is

the inclusion of a costing sheet. Moulding powder can be produced at 4½ annas per lb., apparently including all charges. If, instead of shellac (4 annas per lb.), seedlac or lac recovered from by-products is used, the price would be reduced.

The authors of the brochure also include a cost sheet for the production of 5-amp. switches, the cost per dozen being 1 rupee 11 annas per dozen (pre-war).

2. Shellac-Melamine Plastics

Attempts to harden shellac by acceleration other than urea have led to the use of melamine which has been found to confer improved properties. The procedure of manufacture is similar to that used when employing urea. It is also pointed out that the original alcohol solution can be employed as a short-baking varnish of high heat and water resistance and, moreover, can be used to impregnate jute and cotton fabrics to produce, on hot pressing, a laminated material of remarkable hardness.

3. Shellac-Coal Tar Plastics

With a view to finding cheaper materials which can replace the chemicals used in the foregoing compositions, coal tar reactions with shellac have been examined. Experiments have shown that as much as 25-30 per cent. of dry tar could be compounded with shellac so that less urea and formaldehyde need be added to produce a suitable plastic. As before, the shellac is heated with formaldehyde and coal tar is added. The resin so formed is dissolved in rectified spirit, urea is added and the whole is refluxed. The resin solution so obtained is then mixed with wood flour and calcium stearate, kneaded and air dried. It is then powdered and moulded at 140-145 degrees C. under 1 to 1½ tons per sq. in. pressure. The mouldings develop considerable hardness and heat and water resistance on heating to 120 degrees C. The cost of such a powder (pre-war) when manufactured on a large scale would be of the order of 2-2½ annas per lb., which is probably the cheapest so far known. Only black mouldings are possible, but there is stated to be a need for very cheap moulded slabs either for insulation or for constructional purposes.

4. Shellac-Casein

The difficulties of importing urea and formaldehyde during war-time has turned attention to the necessity of producing powders made entirely of Indian raw materials. Some 400 tons of casein are exported yearly and was considered a suitable raw material for combination with shellac. This has yielded good moulding powders with somewhat less water resistance. The water resistance can, however, be improved by coating moulded articles with shellac-nitrocellulose lacquers and on subsequent baking the products leave little to be desired.

The test bars moulded out of this powder have an impact strength of 3.5 kg. cm./sq. cm. and a heat resistance of 93 degrees C. Subsequent baking improves the heat resistance to over 110 degrees C. without loss of strength. Articles moulded at 135 degrees C. under 1½ to 1¾ tons per sq. in. pressure can be ejected from the press without distortion and take on an excellent gloss when polished. The combination of shellac-formol obtained by heating shellac with formalin and subsequent addition of this to ammoniacal casein has shown promise of better water resistance. This aspect of the problem is now under investigation.

Injection Moulding

The difficulties in using shellac for injection moulding are:—(1) Low softening point, (2) poor tensile strength, (3) partial thermo-hardening. To overcome these disadvantages the softening point and mechanical strength of shellac are raised by the addition of urea and jute waste and the moulding cycle is carefully controlled by working between 100 degrees and 120 degrees C. As with previously mentioned process a costing of mouldings made from such mixtures is given. It is calculated that, using a four-compression mould, bottle caps with screw threads can be made at a cost of 2.0 annas per dozen caps.

FILLERS FOR PLASTICS

Information regarding the effect of fillers on the properties of mouldings, etc., is essential to future development of the industry. In this first section of his article the author deals with the general characteristics of the chief available plastics

By
E. E. HALLS

IN the course of a couple of decades, the plastics industry has evolved from a purposeful but specifically limited activity to embrace interests in practically all avenues of civilization. No longer is it reliant upon a few raw materials of mainly natural origin with the resultant narrow sphere of application. Fundamental research has not only rendered available numerous synthetic plastics, but also established the means for their production under controlled conditions. Industrial activity has ensured the availability of these materials in a range of useful forms to meet the needs of the engineering world, in forms that can be commercially fabricated and assembled with facility. Again, apart from the numerous basic types of plastic, a multitude of materials of widely divergent properties yet having the same plastic binder is available from which to suit the specific needs of service. When it is borne in mind that the conditions of the latter may entail a variety of fluctuating rigours including mechanical stresses of tension, torsion, vibration or impact; electrical phenomenon of insulation leakage, frequency or voltage variation and power losses dissipated as heat; weathering effects of outdoor or indoor service, partial or complete exposure, with fluctuations in temperature and humidity and subjection to moisture condensation; exposure to complete water immersion, oil immersion, or to heat and the possibilities of fire; action by chemical fumes or solutions, solvents such as paraffin or petrol: an appreciation of the fact that one or several of these criteria may have to be catered for to assure satisfactory service for extended periods should convince that the formulation of the plastic material must be correct in all respects.

Plastics provide not merely articles

Table 1.—General Values Showing Broadly the Influence of Filler upon Phenolic Mouldings.

	Nature of Filler			
	50% Wood meal	25% Wood meal 25% Siliceous earth	50% Mica	50% Asbestos
Tensile strength, lb./sq. in.	8,000 to 11,000	7,000 to 9,000	7,000 to 10,000	5,000 to 8,000
Compressive strength, lb./sq. in.	22,000	25,000	19,000	17,000
Flexural strength, lb./sq. in.	5,000	5,390	5,500	3,700
Impact strength, ft./lb.	2.0	1.65	1.35	1.5
Water absorption (24 hours at 20°C.) ..	0.50	0.50	0.05	0.25
Specific gravity	1.35	1.50	1.75	1.90

Table 2.—General Characteristics of Typical Phenolic Mouldings.

Sample No.	Group	Colour	Ash, %	Nature of pigment and mineral filler	Specific gravity at 20°C.	Acetone soluble matter, %	Water absorption (24 hrs. at 20°C.), %	Loss on heating (6 hrs. at 110°C.), %	General type
1	Ordinary wood filled	Black	2.3	Lake dyestuff	1.32	3.7	0.28	0.30	Wood flour filled, electrical quality
2	Ordinary wood filled	Black	3.7	Lake dyestuff	1.31	3.8	0.31	0.50	Wood flour filled, electrical quality
3	General coloured mouldings	Green	7.0	Calcium lake pigment, china clay filler	1.45	10.0	1.0	2.4	Wood flour and mineral filled
4	General coloured mouldings	Red	10.0	Lake dyestuff, lithopone pigment	1.46	4.0	0.15	0.55	Wood flour and mineral filled
5	General coloured mouldings	Black	12.0	Lake dyestuff, clay filler	1.35	3.0	0.80	1.58	Wood flour and mineral filled
6	General coloured mouldings	Red	7.0	Red iron oxide, aluminium oxide	1.35	8.5	0.70	1.80	Wood flour and mineral filled
7	General coloured mouldings	Red-brown	10.0	Red iron oxide, aluminium oxide	1.45	4.5	0.20	0.40	Wood flour and mineral filled
8	General coloured mouldings	Mottled red	7.5	Lake black pigment, mercury sulphide pigment, iron and aluminium oxides	1.40	6.0	0.28	0.80	Wood flour and mineral filled
9	General coloured mouldings	Nut brown	7.0	Iron and aluminium oxides	1.35	7.5	0.28	0.45	Wood flour and mineral filled
10	General coloured mouldings	Yellow-brown	2.7	Dyestuff	1.45	5.8	0.57	1.43	Wood flour filled, no mineral colourant
11	Shock resistance	Black	1.3	Lake dyestuff	1.25	3.5	0.38	0.65	Cotton flock filled
12	Shock resistance	Black	2.0	Lake dyestuff	1.35	5.5	0.20	0.25	Cotton flock and wood flour filled
13	Shock resistance	Black	8.5	Lake dyestuff, diatomaceous earth filler	1.40	4.0	0.82	0.60	Cotton flock and mineral filled
14	Fire resistance	Black	26.5	Lake dyestuff, asbestos and diatomaceous earth	1.85	6.6	0.90	0.85	Asbestos and mineral filled
15	Shock resistance	Black	11.0	Lake dyestuff, china clay filler	1.40	5.9	0.30	0.66	Wood filled and mineral filled
16	Shock resistance	Natural brown	9.8	Siliceous earth	1.58	5.1	1.05	1.45	Kraft paper and mineral filled
17	Dimensional stability and electrical properties	Black	60.5	Lake dyestuff, mica filling	1.80	1.9	0.10	0.10	Mica filled, special electrical grade
18	Dimensional stability under prolonged heat exposure	Yellow	60.7	Clay filler	1.79	1.3	0.15	0.28	Mineral filled, heat resistant
19	Dimensional stability under prolonged heat exposure	Brown	30.0	Clay filler	1.65	1.5	0.10	0.13	Mineral filled, heat resistant
20	Dimensional stability under prolonged heat exposure	Natural	36.5	Clay filler	1.65	8.9	0.15	0.39	Mineral filled, heat resistant
21	Dimensional stability and electrical properties	Black	39.6	Lake dyestuff, mica filling	1.66	3.4	0.08	0.12	Mica filled, special electrical grade
22	Dimensional stability and electrical properties	Natural	43.8	Mica filling	1.66	3.0	0.10	0.16	Mica filled, special electrical grade

of ornamentation, but engineering materials of construction. The engineering industries demand that their materials should meet specifications in which limitations are imposed upon the salient properties or characteristics. Just as in the metallurgical field, a wide range of light alloys, steels, brasses, etc., is available, each member with a purposeful object, and each covered by close compositional, physical and mechanical specifications, so in the plastics field must be available a diversity of types of assured properties within limits, each readily reproduced as required.

The plastic bases themselves, versatile though they may be with respect to range of properties, cannot fully answer the needs of all the fields opened up by their exploitation. Modifying agents properly selected and carefully incorporated in the plastic become essential, and the plastic industries have gone far with the industrial development of this phase. The term "fillers" is broadly employed to describe a large group of raw materials of widely different types that are utilized to this end. They are not mere addition agents or adulterants, diluents or cheapening ingredients, but properly selected ingredients themselves having well-defined properties, incorporated in the plastic by predetermined and controlled methods, with the object of imparting specific characteristics to

Table 3.—General Characteristics of Amino Plastics, Mouldings, Sheet and Tube

Sample No.	Form	Colour	Ash %	Nature of pigment and mineral filler	Specific gravity at 20°C.	Water absorption (24 hrs. at 20°C.) %	Loss on heating (6 hrs. at 110°C.) %	Remarks
1	Moulding	Scarlet	5.0	Dyestuff, zinc oxide	1.50	0.33	2.2	
2	Moulding	Green	2.5	Aluminium lake, zinc oxide	1.48	0.28	2.6	
3	Moulding	Ivory white	2.0	Aluminium oxide	1.50	0.55	3.0	
4	Moulding	Ivory white	6.5	Zinc oxide	1.55	1.20	1.9	
5	Moulding	Ivory white	10.0	Zinc oxide	1.60	0.48	1.7	Cellulose filled and colourant
6	Moulding	Ivory white	12.0	Zinc oxide	1.63	0.61	2.2	
7	Moulding	Blue	7.5	Ultramarine	1.54	0.18	1.9	
8	Moulding	Brown	0.7	Aluminium lake	1.44	0.48	3.5	
9	Moulding	Black	0.2	Aluminium lake	1.43	0.50	3.4	
10	Sheet	Green	6.1	Aluminium lake and zinc oxide	1.58	0.2	1.1	
11	Sheet	Cream	25.0	Siliceous earth	1.69	0.10	2.2	Wood filled and pigmented moulded sheet
12	Tube	White	17.7	Zinc oxide	1.64	0.65	2.35	Wood filled and pigmented moulded tube
13	Sheet	Green	6.8	Aluminium lake, zinc oxide	1.56	0.25	0.8	
14	Sheet	Green	2.2	Aluminium lake	1.50	0.3	1.8	Wood filled and pigmented moulded sheet
15	Sheet	Light blue	1.0	Dyestuff	1.49	0.3	3.3	
16	Sheet	Cream	24.8	Lithopone	—	0.13	2.0	

Table 4.—General Characteristics of Thermosetting (Cellulose Acetate and Benzyl Cellulose) Mouldings.

Sample No.	Group	Colour	Ash %	Nature of pigment and mineral filler	Specific gravity at 20oC.	Water absorption (24 hrs. at 20oC.) %	Loss on heating (6 hrs. at 110oC.) %	Softening point, oC.	Remarks
1	Cellulose acetate	Clear colourless	0.2	Nil	1.32	1.8	2.2	83	No loading
2	Cellulose acetate	Brown	4.5	Dyestuff, manganese and iron oxides	1.34	2.3	2.3	84	Inorganic fillers as well as dyestuff or lake
3	Cellulose acetate	White	15.0	Aluminium and zinc oxides	1.44	1.7	2.1	87	
4	Cellulose acetate	Yellow	18.5	Aluminium lake colour, siliceous earth and aluminium oxide	1.45	3.0	2.8	87	
5	Cellulose acetate	Black	1.0	Aluminium lake dyestuff	1.32	2.9	3.1	86	No loading
6	Cellulose acetate	Brown	2.5	Aluminium lake and iron oxide	1.34	4.8	2.6	95	15% wood flour filler
7	Cellulose acetate	Black	0.44	Dyestuff	1.31	1.2	1.1	83	Note: Coloration without appreciable inorganic material
8	Cellulose acetate	Grey	0.46	Dyestuff	1.33	0.8	1.1	84	
9	Cellulose acetate	White	0.86	Dyestuff	1.31	2.2	1.0	87	
10	Cellulose acetate	Green	0.51	Dyestuff	1.33	2.3	1.0	85	
11	Cellulose acetate	Red	0.87	Dyestuff	1.34	2.8	1.0	87	
12	Cellulose acetate	Maroon	1.15	Dyestuff	1.27	3.2	0.6	87	
13	Benzyl cellulose	Black	30.0	Aluminium lake and siliceous earth	1.55	0.85	0.47	89	Relatively heavy inorganic filling

the resultant product. The filler may be an inorganic or mineral powder, a chopped or ground fibrous constituent of textile, wood, paper or asbestos base, or it may comprise laminæ of paper, fabric or asbestos. The same filler may not successfully incorporate in all plastics although in general for a given purpose choice is restricted to a group or group of fillers independent of the plastic. The hard, resinous plastics such as the phenolic and amino plastics, if pressed or cast into complex shapes, would tend to develop uneven stresses with possibilities of subsequent cracking. They are relatively low in impact strength. Fibrous fillers can correct these shortcomings. Moreover, pure resins are not easy to mould owing to differential shrinkages, and fillers enable this difficulty to be overcome. Likewise stability under heat, cold flow under compression and dimensional changes under variations in atmospheric conditions are typical of quantities that can be modified to some extent by the correct incorporation of filler material. In a broad manner, Table No. 1 shows the modifying influence of various fillers in moulded phenolic resin plastics of the phenol-formaldehyde type.

The fundamental choice of a filler is usually determined by a few well-defined criteria apart from the specific properties it is desired to induce. The filler must be relatively inexpensive and easy to obtain in regular quantities of uniform quality. Natural materials the supply of which is subject to seasonal vagaries have obvious objections. Likewise minerals that vary in physical properties according to their origin, as do the various clays,

are only acceptable if the origin is guaranteed and the supply from that source continuous. The filler must be responsive to incorporation in the plastic by practicable processes. This incorporation must be such that the plastic mass completely "wets" the filler particle, or impregnates it, and such that the mixture is uniform throughout. It must be controllable by specification and simple testing routines. Furthermore, it must be inert and stable and without adverse effect upon the other properties of the plastic mass or upon other ingredients that may be needed in the mix.

The number of plastic bases become almost daily more numerous, but for the present purpose they can briefly be grouped as follows:—

(a) Phenolics, with the phenol-formaldehyde condensation product as the principal representative.

(b) Amino plastics, the condensation products from urea or thiourea, or a mixture of the two.

(c) Cellulose acetates.

(d) Nitro cellulose products.

(e) Benzyl cellulose.

(f) Rubbers and ebonites.

(g) Casein group.

(h) Polystyrols.

(i) Polyvinyls.

(j) Shellacs and similar compositions.

(k) Bituminous plastics.

It is proposed to discuss filler materials in relation to these plastics and then to illustrate some of the salient features with comparative

Table 5.—General Characteristics of Loaded Soft Rubbers.

Sample No.	Colour	Type	Mineral matter content %	Nature of mineral matter	Other compositional data, %				Remarks
					Sulphur combined with rubber	Free sulphur	Acetone soluble matter	Hardness shore durometer	
1	Grey	Natural	52.8	Chalk, siliceous earth, some zinc oxide	0.80	0.24	5.8	68	—
2	Grey	Natural	20.8	Zinc oxide	0.17	0.27	4.0	57	Selenium content 0.30%
3	Grey	Natural	31.2	Zinc oxide, chalk	1.4	0.41	8.4	52	—
4	White	Natural	50.8	Zinc oxide	0.22	0.33	4.1	59	—
5	Black	Natural	7.9	Zinc oxide	1.45	0.22	4.1	79	—
6	Grey	Natural	31.8	Zinc oxide	1.05	0.07	3.3	50	—
7	Grey	Natural	8.5	Zinc oxide	7.9	0.22	6.6	44	—
8	Grey	Natural	38.5	Zinc oxide	0.50	0.04	2.1	60	—
9	Grey	Natural	29.8	Zinc oxide	2.0	2.5	3.6	66	—
10	Grey	Natural	49.7	Zinc oxide	2.1	0.9	2.5	80	—
11	Grey	Natural	69.3	Zinc oxide	1.0	0.45	1.5	65	—
12	Red	Natural	12.4	Iron oxide	1.5	0.23	5.9	45	—
13	Red	Natural	8.5	Antimony sulphide, zinc oxide, traces talc	3.1	0.14	4.7	45	—
14	Black	Natural	54.3	Chalk and zinc oxide	1.3	0.29	4.8	75	—
15	Grey	Synthetic	8.0	Zinc oxide	50.0	8.2	8.0	60	Thiokol type
16	Grey	Synthetic	10.5	Zinc oxide	0.11	0.02	10.0	70	Neoprene type Chlorine content 13.2%
17	Grey	Synthetic	5.0	Zinc and magnesium oxides	1.1	0.91	6.2	96	Neoprene type Chlorine content 13.3%
18	Grey	Synthetic	4.6	Zinc and magnesium oxides	0.42	0.06	9.8	61	Neoprene type Chlorine content 14.5%
19	Grey	Synthetic	3.4	Zinc oxide	0.60	0.70	15.4	65	German "Buna"

Table 6.—General Characteristics of Hard Rubbers or Loaded Ebonites.

Sample No.	Colour	Type	Mineral matter content %	Nature of pigment and mineral filler	Other compositional data, %					Remarks
					Specific gravity at 20°C.	Sulphur combined with rubber	Free sulphur	Acetone soluble matter	Alcoholic potash soluble	
1	Red	Red hard rubber	55.0	Mercuric sulphide (vermilion)	2.12	12.0	0.1	1.5	2.5	Used for electrical purposes under tropical conditions, for stability of dimensions and insulation
2	Red	Red hard rubber	41.5		1.90	13.0	0.05	4.5	1.8	
3	Red	Red hard rubber	31.5		1.58	13.5	0.05	2.0	2.8	
4	Brown	Red hard rubber	49.0	Antimony sulphide	1.98	5.4	0.05	2.8	1.9	
5	Brown	Red hard rubber	50.0	Antimony lake pigment, talc and china clay	1.90	12.8	0.7	1.0	0.5	
6	Brown	Red hard rubber	40.0	Antimony sulphide pigment, china clay and zinc oxide	1.74	11.3	0.9	2.5	1.0	Satisfactory electrically but used for artistic and decorative purposes, e.g., fountain pens
7	Green	Decorative	70.0	Lake pigments, zinc oxide and china clay	1.60	11.6	0.2	3.0	1.0	
8	Red	Decorative	35.0		1.57	15.0	0.1	3.0	2.0	
9	Mauve	Decorative	50.0		1.60	13.1	0.2	3.7	0.6	
10	Brown	Electrical	47.0	Antimony sulphide pigment (7%), china clay	1.75	11.0	2.5	1.3	0.5	Electrical purposes, low power factor at high frequency
11	Brown	Electrical	36.0	Antimony lake pigment and zinc oxide	1.58	20.0	0.5	2.5	1.0	Electrical purposes, suitable for hot deformation
12	Natural	Electrical	13.0	Titanium dioxide	1.40	21.5	0.2	4.5	0.5	Suitable for flexible tubing, capable of cold deformation
13	Natural	Electrical	12.5	10% zinc sulphide, 2½% magnesium oxide	1.35	22.0	0.3	5.0	0.5	Electrical purposes, low power factor at high frequencies. Suitable for cold punching
14	Natural	Electrical	11.5	9% aluminium oxide, 2½% magnesium oxide	1.30	21.5	0.1	2.6	0.5	
15	Natural	Electrical	12.5	10% lithopone, 2½% magnesium oxide	1.40	22.5	0.1	1.6	0.5	
16	Black	Electrical	1.0	—	1.15	30.0	0.5	4.0	2.0	Average non-loaded black ebonite
17	Black	Mechanical or chemical	20.0	Siliceous earth	1.40	21.5	2.0	4.3	1.5	Hard ebonite for chemical resistance

tabulated data. The fillers covered embrace the following:—

Fibrous Fillers.

Wood flour.
Wood pulp.
Asbestos.
Cotton flock and linters, silk flock, and chopped cotton fabric.
Paper (as a filler in moulding powders).

Mica.

Mineral powder fillers.
Other filling agents.

Paper, fabric and asbestos in laminated products will be omitted from the present article. Pigments used for colouring will be included among the mineral powder fillers.

Brief notes will first be given appertaining to the nature and properties of the fillers themselves, and these will be followed by information relative to their use in specific plastics. To provide a broad visualization of the possible field, a review of analytical and other test data appertaining to loaded plastics is truly informative. To this end, representative data have been compiled in tabular form as under:—

Table 2. Phenolic mouldings.
Table 3. Amino plastics.
Table 4. Thermoplastic mouldings (cellulose acetate and benzyl cellulose).
Table 5. Soft rubbers.
Table 6. Hard rubbers and ebonites.
Table 7. Casein plastics.
Table 8. Shellac base mouldings.
Table 9. Bituminous mouldings.

Table 7.—General Characteristics of Casein Plastics, Sheet, Rod and Mouldings.

Sample No.	Form	Colour	Ash %	Nature of mineral matter	Specific gravity at 20°C.	Water absorption (24 hrs. at 20°C.) %	Loss on heating (6 hrs. at 110°C.) %	Remarks
1	Moulding	Cream	8.8	Zinc oxide, some magnesium oxide and calcium phosphate	1.34	6.7	4.8	All normal alkaline casein mixtures, having 5 to 10% zinc oxide loading, and lake pigment or dyestuff
2	Rod	Red	7.5	Aluminium lake, zinc oxide, some magnesium oxide and calcium phosphate	1.33	5.0	3.2	
3	Rod	White	10.0	Aluminium lake, zinc oxide, some magnesium oxide and calcium phosphate	1.36	5.1	3.2	
4	Rod	Blue	8.5	Aluminium lake, zinc oxide, some magnesium oxide and calcium phosphate	1.35	5.1	3.0	
5	Rod	Green	8.5	Aluminium lake, zinc oxide, some magnesium oxide and calcium phosphate	1.34	3.1	2.8	
6	Rod	Yellow	8.0	Aluminium lake, zinc oxide, some magnesium oxide and calcium phosphate	1.34	4.0	2.8	
7	Sheet	Red	5.0	Aluminium lake, zinc oxide, some magnesium oxide and calcium phosphate	1.33	8.5	12.0	
8	Sheet	White	12.0	Aluminium lake, zinc oxide, some magnesium oxide and calcium phosphate	1.31	6.5	6.0	
9	Sheet	Blue	10.0	Aluminium lake, zinc oxide, some magnesium oxide and calcium phosphate	1.36	6.5	5.5	
10	Sheet	Green	10.0	Aluminium lake, zinc oxide, some magnesium oxide and calcium phosphate	1.34	7.0	7.5	
11	Sheet	Yellow	9.0	Aluminium lake, zinc oxide, some magnesium oxide and calcium phosphate	1.33	6.8	7.2	

Reference will be made to individual items in these tables later. Regarding methods of test for the data given, these were standard. For the thermo-setting (ammo and phenolic) materials, mineral loading was determined from the ash on complete incineration, owing to the complexities of direct analysis. Prior to water absorption and loss on heating tests, specimens were conditioned at 75 per cent. humidity and ordinary temperatures (20 degrees C. ± 2 degrees) in order to bring specimens to a uniform condition. (The same conditioning was employed for all specimens subjected to the stability tests included in later tables.) The softening point determinations on the thermoplastics were made on a plunger type of test, using the

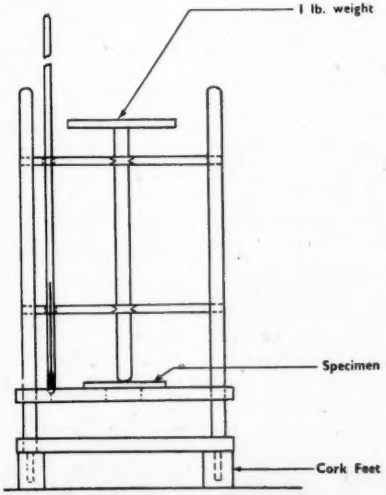


Fig. 1.—General layout of softening point apparatus for thermoplastic materials.

Table 8.—General Characteristics of Typical Shellac Base Mouldings.

Sample No.	Colour	Ash %	Nature of mineral loading	Specific gravity at 20°C.	Water absorption at 20°C. %	Loss on heating (6 hrs. at 110°C.) %	Acetone soluble resins %	Remarks
1	Black	50.0	China clay	1.86	0.15	0.30	27.0	Natural resin mineral filled mixture
2	Black	39.0	China clay	1.64	0.10	0.45	28.5	Natural resin mineral filled mixture

Table 9.—General Characteristics of Typical Bitumen Base Mouldings

Sample No.	Colour	Ash %	Nature of mineral loading	Specific gravity at 20°C.	Water absorption (24 hrs. at 20°C.) %	Loss on heating (6 hrs. at 110°C.) %	Softening point °C.	Acetone soluble resins %	Remarks
1	Black	25.0	China clay and barium sulphate	1.70	0.02	0.10	85	15.0	Mineral filled/resin/bitumen mixture, approx. 60% bituminous matter
2	Black	40.0	China clay	1.53	0.03	0.12	105	38.0	Mineral filled/resin/bitumen mixture approx. 20% bituminous matter
3	Black	52.5	Iron/aluminium clay	1.65	0.02	0.13	107	20.0	Mineral filled/resin/bitumen mixture, approx. 25-30% bituminous matter
4	Black	40.0	Asbestos and iron/aluminium clay	1.43	0.02	0.14	110	14.0	Asbestos and mineral loaded resin/bitumen mixture, approx. 45% bituminous matter.
5	Black	70.0	Asbestos	1.91	0.25	0.28	112	6.3	Asbestos filled resin/bitumen mixture, approx. 25% bituminous matter.

apparatus shown in Fig. 1. It comprises a framework carrying two horizontal plates, $\frac{1}{2}$ in. apart, the upper one 0.20 in. thick, having a central hole of $\frac{1}{2}$ in. diam. The specimen, reduced by machining to $\frac{1}{16}$ in. thickness, is laid over this hole and the plunger brought to rest upon it. The plunger is $\frac{1}{4}$ in. diam., and operates freely between two guides. The platform at its upper end is loaded to a weight of 1 lb. inclusive of the plunger itself. The whole set-up can be heated gradually by means of a water bath at a rate of 5 degrees C. per minute. The softening point of the specimen is read as that at which the extruded sheath of plastic reaches the lower plate, or at which the extruded dome fractures, whichever first occurs. This temperature is indicated by a thermometer in the bath, which, of course, must be kept stirred to maintain uniformity of heat throughout.

(To be continued)

Packaging Order

The first of the new Packaging Orders which came into force on July 23 restricts the types of materials that may be used for packing commodities other than food and includes plastics and such materials. Copies of the Order may be obtained from H.M. Stationery Office. The B.S.I. Schedule No. 1048, published in connection with it, is sold at 5s.

PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

SHIPMENT OF GOODS.—The Board of Trade and the Commissioners of Customs and Excise announce that it has been found necessary to withdraw the concession under which goods have hitherto been allowed to be shipped after the date of expiry of the relative export licence, provided that they were pre-entered with the Customs before that date. From now onwards goods must be shipped within the period of validity of an export licence. Where, however, Customs officers are satisfied that the goods to be exported under export licence had been pre-entered with the Customs and had reached the loading berth before the licence had expired but had been shut out through circumstances beyond the exporter's control, a period of grace not exceeding 15 days may be allowed. Holders of export licences should therefore be careful to note the date of expiry of the licence, and if there appears to be no prospect of shipping the goods before the licence expires, they should apply to the issuing authority for the renewal of the licence at least a fortnight before the date of expiry.

"BLACK - OUT" VENTILATION.—Hurried measures taken on the outbreak of war to black-out factories often resulted in serious interference with the means of ventilation and affected the health and productive capacity of the workers. Much has since been done to remedy the defects, but the subject remains one of pressing importance, particularly in the summer months. A pamphlet—Factory Ventilation in the Black-out (Form 301)—was issued in the early part of the War and has now been re-issued in a slightly revised form by the Factory Department of the Ministry of Labour and National Service. The pamphlet describes briefly the various measures which can be taken to improve ventilation without permitting the escape of interior artificial light, such as mechanical ventilation, provision of light-trap ventilators and stimulation of air movement. A number of drawings are included showing simple ideas for the construction of light-traps at ventilator openings, such as windows and other wall and roof openings.

Copies of the pamphlet may be purchased from H.M. Stationery Office.

MINISTRY OF WORKS AND BUILDINGS.—A Plastics Committee has been set up to report to the Ministry of Works in regard to the use of plastics in houses. The Committee is convened by the British Plastics Federation and it has been divided up into different material groups.

The members of the Committee are as follow:—

Chairman: H. V. Potter (Bakelite, Ltd.).
Secretary: G. T. Beach (British Plastics Federation).
T. L. Birrell (BX Plastics, Ltd.).
E. A. Blanch (Kork-N-Seal, Ltd.).
H. Bridge (T. de la Rue and Co., Ltd.).
C. S. Dingley (Streetly Manufacturing Co., Ltd.).
Major S. M. Mohr (Micanite and Insulators, Ltd.).
W. M. C. Norie (I.C.I. (Plastics), Ltd.).
Dr. R. J. Schaffer.
A. E. Skan (Ellison Insulation, Ltd.).
R. H. Sheppard, A.R.I.B.A.
F. E. Townrow, A.R.I.B.A.
S. Whyte (Consultant).

PLASTICS CONTROL of the Ministry of Supply has moved to Universal House, 56, Buckingham Palace Road, London, S.W.1. (Telephone, Sloane 9985.)

COURTAULDS, LTD.—We have been requested by Colman, Prentis and Varley, Ltd., to point out that the change of address of their client, Courtaulds, Ltd., to 16, St. Martin's le Grand, London, E.C.1, referred only to the removal of the advertising department.

CELANESE PLASTICS DEVELOPMENT.—The registration as a private company of Celanese Plastics Development was made in July, with a capital of £300,000 in £1 shares. Registered offices are at Celanese House, W.1, the headquarters of British Celanese.

ALBERT PRODUCTS LTD.—This company announces that the whole of its share capital has been acquired by Imperial Chemical Industries Ltd. Arrangements are being made for the manufacture of the well-established range of "Albertol" and "Alprokyd" synthetic resins.

Resinoids and Other Plastics as Film Formers

By B. J. BRAJNIKOFF,
Consulting Electrical Engineer

X.—Cross-Polymers of Styrene

THE method of Nature, with limitless resources, is to produce an enormously redundant supply and to evolve the best through a multiplication of chances; it is therefore, in a high degree, wasteful. The economy of Nature is the absence of economy. The properties of matter are hidden and must be searched for, and their purposeful utilization is an exclusively human power. In fact, the method of mind, whose directive force and prevision alone can know how to economize, is the precise opposite of the way of Nature.

One of the very efficacious means of evolving high quality plastics is the formation of cross-polymers by combining judiciously the desired characteristics of several individual classes of resins.

It should be noted, however, that, despite many certain possibilities incident to this method, its development at present is just at an embryonic stage.

Pre-polymerized Styrene as Dielectric

It could hardly be doubted that the research in this direction will in a not far distant future render feasible many things that seem now quite unattainable. The polymerized resins, which are principally based upon organic substances containing the vinyl group, have proved to be of special interest in the sense of their mutual compatibility as well as the ability to mix with a variety of different reagents. One of the leading places among them should be assigned to styrene.

Prior to the detailed examination of the co-polymerization processes proper, mention should also be made of another interesting aspect of film-forming and impregnating systems derived from styrene, namely, the possibility of utilizing them in the electrical field as monomer and polymer by the method evolved by the International General Electrical Co. of New York in conjunction with the Allgemeine Electricitäts Gesellschaft of Berlin.[114]

The application of varnishes or impregnants obtained from resinoids by dissolving them in organic solvents is attendant frequently by a great technical difficulty due to the fact that the removal of solvents, even if performed with extreme care in vacuum treatment, cannot ensure coatings free of blisters; these faulty parts unavoidably affect the insulating capacity of electrical apparatus and thus reduce its efficiency.

This disadvantage, according to the above process, may be obviated by producing coating media that are free of solvents by using styrene as the parent substance, and by applying them both in the form of monomeric styrene and in the form of a solution of polystyrene in monomeric styrol, with the subsequent thermo-hardening at 100 to 180 degrees C. for about two hours.

The operation can be effected in any convenient manner, in presence or absence of catalytic, colouring or other conditioning agents, and polymerized finally by heat treatment with or without pressure, resulting in perfectly dense and homogeneous films or a uniform impregnation.

The Effect of Air Occlusions in the Films

The influence of air spaces interposed between the electrical insulating materials (as well as gaseous occlusions within them) on the reduction of their dielectric

strength due to distortion of potential gradient by different intervening media, may be illustrated by the following example.

Consider the case of a parallel plate electrical condenser, which is insulated by the interposition of cardboard impregnated with polystyrene resin, having the distance between the plates $d = 0.5$ cm. To estimate the percentage decrease of the disruptive strength of insulation, if between the cardboard and the condenser plates, there is an air clearance $d_2 = 0.02$ cm.

Assuming the permittivity for the polystyrene treated cardboard $e = 4e_0$, where e_0 is the dielectric constant of a vacuum, which for practical purposes may be taken equal to the dielectric coefficient of air, $e_2 = e_0$. Let the dielectric strength of the polystyrene treated cardboard $E_{1\ max.} = 200\ \frac{kV}{cm.}$, and for air (non-conditioned) $E_{2\ max.} = 21 \frac{kV}{cm.}$, respectively.

The thickness of the cardboard insulation $d_1 = d - d_2 = 0.48$ cm. The dangerous medium is the air layer. Since the intensities of the electric field in various insulating media are related as the inverse ratio of their permittivities, it follows that

$$V_1 = E_{2\ max.} \left(d_2 + d_1 \frac{e_2}{e_1} \right) = 21 \frac{kV}{cm.} \times \left(0.02 + 0.48 \times \frac{1}{4} \right) cm. = 2.94 \text{ kV}.$$

If the whole space were filled with the cardboard, then the maximum breakdown potential would be

$$V_2 = 200 \frac{kV}{cm.} \times 0.5 \text{ cm.} = 100 \text{ kV}.$$

Whence, consequently, the actual reduction of the dielectric strength of the polystyrene insulation in the specified condenser system is:—

$$\frac{V - V_1}{V_2} \times 100\% = \frac{100 - 2.94}{100} \times 100\% = 97\%.$$

The foregoing example clearly shows the importance of an appropriate vacuum impregnating process in order to prevent the local discharges in electric cables, machine-wound coils and other elements of electric systems.

Co-polymerization of Styrene and Acrylic Derivatives

Recognizing the potentialities of combining styrol and methacrylic resins, each of which has proved its outstanding merits in the manufacture of organic glass, film-forming vehicles, and other compositions,[116] giving strong, transparent, colourless products, Professor Rutovsky and his co-workers in Russia recently subjected these substances to a thorough exploration and showed that they possess many possibilities.

The only known fact concerning the cross-polymerization of styrene and acrylic derivatives is that such a reaction between styrol and the esters of acrylic acid and its homologues (not below butylacrylate) yields soft polymeric products;[117] the addition to styrene up to 5 per cent. of acrylic and methacrylic acids increases their thermal stability and the resistance to bending.[118] With regard to co-polymerization of styrene with methyl methacrylate and the nature of the derived products, the information is extremely meagre, and a few available patents disclose no data as to details of the process and properties of the polymerizates.[119]

Experimental Procedure

In order to ensure the purity of styrene it has been subjected to multiple distillation, in presence of hydroquinone (to prevent its polymerization), at the atmospheric pressure, in a still fitted with a dephlegmator 25 cm. high. The fractions employed in experiments boiled between 143 and 147 degrees C. Prior to use the styrene was freed from the hydroquinone by keeping it over caustic potash for two to three days, and then distilled at a reduced pressure of about 10 to 20 mm. Hg., utilizing the vacuum fractions within the limits of 3 to 5 degrees C.

The product thus obtained gave the following constants:—

Specific gravity $D_4^{14.5}$ 0.9078.

Refractive index n_D^{15} 1.5435—1.5458.

Molecular refraction R = 36.4.

Molecular refraction as theoretically calculated = 35.08.

Bromine number (by Knopp test) 136-140, which corresponds to the styrene content of 89 to 91 per cent.; the repeated distillations of styrol failed to raise the bromine number.

The methyl methacrylate employed for the co-polymerization with styrene was in a very high state of purity, boiling out between 99 degrees and 101 degrees C.

The methyl methacrylate constants were:—

Specific gravity D_{20}^{20} 0.9498.

Refractive index n_D^{15} 1.4163.

Refractive index n_D^{20} 1.4150.

Molecular refraction R = 26.3.

Molecular refraction theoretical = 26.40.

The benzoyl peroxide, used as catalyst, was twice re-crystallized from alcohol, fused at 104-104.5 degrees C., and contained 98.5 per cent. of the theoretically estimated active oxygen, determined according to Gelissen and Hermans.[120]

The polymerization of styrene, methyl methacrylate and their mixtures has been conducted in all cases at 80 degrees C., with the addition of 1 per cent. of benzoyl peroxide by the three methods, namely: (1) mass polymerization, (2) in solvents, and (3) in aqueous emulsions.

The application of higher temperatures was avoided, since it would hinder the carrying out of the process, particularly in the emulsion form.

The introduction of smaller quantities of catalyst would tend to increase the duration of the methacrylate polymerization, but would drastically retard the styrene reaction, and the work at different temperature levels and with various amounts of catalysts would lead to results that would be impossible to compare.

(1) Mass Polymerization

The mass polymerization was carried out with the object of determining the technological characteristics of the process and the resultant products in the most direct manner. The process was performed in the sealed glass vessels, kept on the water bath for eight hours. It has been noticed that after five to six hours all specimens lost fluidity at 80 degrees C. The derived polymers were transparent and water-white.

The specimens consisting of methacrylate without styrene, and also with the addition of 5 per cent. of styrol, were highly blistered, those comprising 25 per cent. of styrene were considerably more homogeneous, and the rest of specimens were almost entirely free of blisters.

Molecular weights of polymers, the values of which are given in Table 1, have been calculated on the basis of viscosities of toluol solutions as determined by the Ostwald method. In each case the molecular weight of the fundamental molecule was taken as 100, which cannot introduce appreciable error into the final results.

Table 1.—Determination of the Molecular Weights of Methacrylate-Styrene Polymers[121]

Content, %		Catalyst concentration	Specific viscosity	Molecular weight
Styrene	Methacrylate	$C_{mol.}$	$\eta_{sp.}$	
0	100	0.033	0.043	7,200
5	95	0.043	0.123	16,000
25	75	0.038	0.147	22,000
50	50	0.050	0.178	20,000
75	25	0.041	0.106	14,000
95	5	0.049	0.158	18,000
100	0	0.045	0.115	14,000

The relationship between the composition of the test polymers and their molecular weight was shown to obey the following law.

The low values of molecular weights were consequential to the comparatively rigid conditions of the polymerization procedure.

The low molecular weight of the polymethyl methacrylate, which is lower than the molecular weight of polystyrene, and also the maximum value of the molecular weights with the 25 to 30 per cent. of styrene content, may be explained in this

way: the rapid exothermic polymerization of methyl methacrylate gives rise, even with such small proportions of the reagent, to its considerable overheating, which, in turn, induces a further acceleration of the reaction and results in the formation of low molecular polymers.

The addition of styrene promotes the double effect: first, it retards the polymerization of methacrylate, which favours the production of polymers with the greater length of chain. Secondly, the dilution of methacrylate by styrene should lead to the formation of the products with a lower molecular weight. In cases of smaller additions of styrene, the first factor prevails; with the greater proportions—the second prevails. As a consequence of the operation of the said agencies, the resulting polymers are of the maximum molecular weight.

The very fact of the production of transparent, homogeneous polymers (contrary to views held by some investigators,[122] that polystyrene and polymethyl methacrylate are incompatible), clearly indicates that the body obtained is not a mixture of polymers of styrol and methyl methacrylate, but is a true cross-polymer. This is confirmed by the following consideration.

The product derived from the polymerization of 50 per cent. of styrene and 50 per cent. of methacrylate is totally soluble in hot acetic acid, whereas polystyrene is entirely insoluble in it. A part of the above substance (about 60 per cent.) is precipitated from the acetic acid solution, and the remainder is released by means of water. Both fractions were washed, dried in vacuo, and analysed by the Zeisel method in the modification of Kirpal and Buna.[123] The determination of ester groups by the Zeisel method, according to Staudinger,[124] is quite applicable for the analysis of polyacrylic esters, whilst their saponification can be effected with the aid of concentrated acids or alkalis. It has been suggested that, prior to the Zeisel analysis of resins containing methyl methacrylate, it is desirable to carry out the thermal depolymerization of the product. From the experiments it has been found that the Zeisel method, with the addition of 10 to 15 per cent. of acetic anhydride to hydrogen iodide, is quite suitable for the quantitative estimation of polymethyl methacrylate, but the length of time required for the splitting off of methoxyl groups is increased up to 25 to 30 hours. The study of polymers has confirmed these conclusions.

The first fraction of polymers, precipitated by cooling, contained 14.8 per cent. of methoxyl groups, the second fraction, liberated by water, 14.4 per cent. No determination of molecular weight has been made of the first fraction, that of the second fraction was found to be equal to 11,000, as against 20,000 of the non-fractionated mixture. This result shows that the molecules of methacrylate are uniformly distributed throughout polymers of various chain lengths, and confirms the fact of absence in the body of the resin of either individual polystyrene, or polymethyl methacrylate units as such.

Therefore, the claims put forward by several workers for producing co-polymers by means of gradual incorporation, as the reaction progresses, of a quickly polymerizable component to a more slowly polymerizing substance,[125] in the light of these results, are entirely unfounded and possess no technical advantages.

(2) Polymerization in Solutions

The polymerization in solvent media was accomplished by using 10 per cent. solutions of styrene, methyl methacrylate, and their mixtures in pure methanol, as well as in methanol containing 30 per cent. of water. The following constants specify the methanol employed in this work:—

Specific gravity $D_4^{17} = 0.7954$
Refractive index $N_D^{15} = 1.3324$

The amount of benzoyl peroxide used as catalyst was 0.5 per cent., calculated on the weight of the monomeric substance. The process was conducted in sealed glass vessels at 80 degrees C., controlled by an air thermostat.

The results obtained showed that styrene was poorly soluble in mixtures of methanol with water, but the main objectionable feature of polymerizing styrene in this way, both with methacrylate and alone, in all examined cases, is that polymers are precipitated and coalesce at the bottom of the reaction vessel as a resinous mass. The resinous drops falling out during the first hours of the polymerization are still fluid or semi-fluid and apparently consist of the polymerized substance with a small quantity of methanol dissolved in it. All this creates operating difficulties in the laboratory work and renders this method entirely unacceptable for the large-scale manufacture.

(3) Emulsion Polymerization

The polymerization in water emulsions was carried out at 80 degrees C. and catalysed by 1 per cent. of benzoyl peroxide. With small quantities of the charge, a wide test tube served as the reaction vessel, fitted with a reflux condenser, through which passed the shaft of the stirrer, the propeller making about 500 revolutions per minute; the heating was carried out on a water bath.

The larger amounts of monomeric materials were polymerized under similar conditions, using a flask equipped with a screw-stirrer. The charge of monomeric substance, with benzoyl peroxide dissolved in it, was poured into a preheated aqueous solution of emulsifying agent and rapidly dispersed by the agitator.

The suspension of polymers obtained after the polymerization was made to coagulate by pouring it, while stirring, into a container filled with methanol, which amounted to a half of the polymeric product. A white powder-like precipitate of the polymer was filtered, washed with boiling methanol in a vessel fitted with the agitating device, filtered again, and dried under reduced pressure of 20-30 mm. Hg., at a temperature of 80 degrees to 90 degrees C., for two to three hours.

The Influence of Emulsifiers and Diluents on Polymers

Since many patents[126] recommend ammonium oleate as a very efficient emulsifying agent for styrene, it was deemed of interest to check this claim by experimental tests.

It has been found that styrene emulsions in the presence of ammonium oleate are quite stable in the cold, but rapidly separate on heating without stirring. The emulsions of methyl methacrylate with oleate of ammonium slowly stratify at room temperature. The oleate of ammonium employed in this work was prepared by mixing 19 grammes of oleic acid distilled in vacuo, 5 c. cms. of 25 per cent. ammonia, and 48 c. cms. of water; that is, it contained approximately 28 per cent. of pure oleate.

As the patent specifications stress the necessity for excess of ammonia, the tests were made by applying a neutral oleate, as well as oleate with the addition of an additional 25 per cent. of ammonia. The duration of the experiment in polymerizing styrene, in a number of cases, was extended up to 12 hours, although, according to Houz and Adkins,[127] 10 hours was quite sufficient for the purpose.

No solid polymers were produced by polymerizing styrene in the presence of ammonium oleate. The coagulation of media released a sticky paste-like mass, which was probably the solution of polystyrene in monomeric styrene. By dissolving this mass in toluol and then precipitating it with methanol, a solid polystyrene, with the yield of about 5 per cent., has been obtained. The above experiments have thus demonstrated a complete unsuitability of ammonium oleate for the polymerization of styrene in the presence of catalysts of the peroxide type.

Further experiments were conducted to test another group of emulsifying agents, namely, ammonium salt of sulphonated recinolic acid, or the so-called alizarine oil. Certain patents[128] specify as emulsifying agents for co-polymerizing acrylic derivatives with other substances, the

mixture of 1 per cent. of the alizarine oil and 0.5 per cent. of sodium salt of isopropylnaphthalene sulphonic acid.

The action of the alizarine oil proved to be inadequate, and the resulting polymer was in the form of a continuous lump stuck to the stirrer. The formation of such lumps has been averted by introducing 10 per cent. of the alizarine oil and 10 per cent. of ammonium oleate during the polymerization of styrene, or in the case of polymerizing styrene, methacrylate and their mixtures, by the addition of 10 per cent. of the alizarine oil, 10 per cent. of ammonium oleate, and 10 per cent. of 25 per cent. ammonia, calculated on the quantity of the monomers. Under these conditions, methacrylate yields 93 per cent. of low molecular polymers, and the yield of styrene amounts merely to 60 to 65 per cent. During the polymerization of methacrylate either singly, or in conjunction with styrene, a certain proportion of polymers is formed, coagulates as the reaction advances, and settles down in the shape of small grains.

The next type of emulsifying agents examined was coconut soap. The sodium soap has been prepared from the coconut oil, crystallized from aqueous solution by means of common salt, washed with cold water, comminuted and dried at 30 degrees to 35 degrees C. for five hours. Since the soap was not entirely dry, it has been used in proportion up to 10 per cent. on the amount of the monomeric component.

The polymerization process with the coconut soap proved to be quite satisfactory. On diluting the emulsion in the ratio 1 : 4 and applying a single-blade homogenizer, it has been noticed that resinous lumps begin to form on the stirrer. The increase of the degree of dilution up to 1 : 5 led to a complete averting of lump formation. In absence of such ball formation, the yield of polymethyl methacrylate was of the order of 80 to 87 per cent., and the polystyrene yield, estimated on 100 per cent. of the monomer used, attained 94 per cent. The actual yields of polymers in all cases were somewhat higher still than those mentioned above, due to losses inevitable in different manipulations during their treatment. In polymerizing pure methyl methacrylate and the mixtures containing it, not less than 50 per cent., a considerable proportion of the product, as before, precipitated in the course of the reaction in the form of tiny grains. The size of grains reached about 2 mm., and they were easily reducible by crushing to a pure white powder.

Molecular weights of polymers produced with the aid of coconut soap are appreciably higher than polymers derived from the mass polymerization of monomers, or in emulsions prepared with alizarine soap and ammonium oleate. The observed relationship between molecular weight and the composition is as follows:—

With the increase of the styrene content in the initial mixture, the molecular weights of polymers fall rapidly at first, then more slowly.

The data relating to the calculated molecular weights are presented in Table 2, given below.

Tabie 2.—The Calculation of Molecular Weights of Styrene-Methacrylate Co-polymers[121]

Content, %		Catalyst concentration	Specific viscosity	Molecular weight
Styrene	Methacrylate	$C_{mol.}$	$\eta_{sp.}$	
0	100	0.1180	3.9	84,000
0	100	0.0364	0.747	89,000
25	75	0.0360	0.414	54,000
50	50	0.0368	0.353	46,000
95	5	0.0448	0.370	39,000
95	5	0.0368	0.288	39,000
100	0	0.1220	1.000	34,000
100	0	0.0420	0.378	44,000

Deductions

A.—The polymerization of mixtures of styrene and methyl methacrylate leads to the formation not of mechanical mixtures of polymers of the original reagents but to new chemical units—true co-polymers with approximately uniform distribution of molecules of the parent

substances in polymeric chains. There is not the slightest need for the gradual addition of the more rapidly polymerizing methyl methacrylate to a more slowly reacting styrene, as has been emphasized by several patent specifications.

B.—The co-polymerization of styrene and methyl methacrylate under a rigid set of conditions (e.g., in mass polymerization of monomers with a considerable proportion of catalysts) results in the formation of low-molecular cross-polymers. The influence of the added styrene, as retarder of the reaction and as diluent, leads to the production of polymers with higher molecular weights, which attain a maximum with a certain proportion of styrene content.

C.—The polymerization of styrene and its mixtures with methyl methacrylate in the presence of diluents (in particular in methanol and its water mixtures, which are the best-known diluents for polymerizing methacrylate) in actual practice are exceedingly difficult, owing to the tendency of styrene, soon after the start of the reaction, to separate out of the solution and then to polymerize to resin independently.

D.—The emulsion polymerization method here, as on previous occasions, proves itself to be the best procedure both in the technical and economic sense, giving co-polymers with comparatively high molecular weights and very good yields of the order of 80 to 94 per cent. Molecular weights of co-polymers display a gradual falling off on passing from pure methyl methacrylate to pure polystyrol.

E.—Ammonium oleate, suggested in various patents as emulsifying agent for polymerizing styrene, is inapplicable when using catalysts of a peroxide nature.

F.—Coconut soap is a satisfactory emulsifier for methyl methacrylate and its mixtures with styrene. The small grains of the polymeric product released during the reaction are of high chemical purity and are easily reducible to powder.

G.—The lump formation occurring in the course of the emulsion polymerization can be prevented by preparing emulsions of lower concentration.

Role of Styrene in Synthetic Latex Systems

Among the productive processes in plastics technology the method of emulsion polymerization is gaining recognition as an efficacious means of performing difficult reactions involving numerous components.

The emulsion method of the co-polymerization, therefore, becomes of distinct advantage in developing hybrid products, as it allows a considerable extension to be made in the range and variety of permutations and combinations of reagents. The emulsion process is thus especially useful in the production of heteropolymers destined to provide a series of film-formers of great utility.

However, in dealing with emulsions, the first point to note is that to build up a stable colloid system fitted for polymerizing several primary monomeric substances and catalysts involves the help of many auxiliary agencies; the correct formulation of such substituents as emulsifying agents, protective colloids, electrolytes, the pH adjusters, plasticizers, regulators of the particle size of the emulsion and distribution of the continuous phase (water) and others, seems rather complicated and in some cases might present even difficulties.

None the less, in spite of the apparent complexity of emulsion polymerization its working in actual practice, once the system was duly constituted, offers no further handicaps.

One of the most valuable and logical contributions of application of the emulsion method has been in the development of latex-like and kindred compounds, the importance of which the present writer had stressed in his works as far back as 1930.[129] The potentialities of the emulsion process were quickly grasped in Germany and the U.S.A., where it is now practised on an ever-growing scale, sometimes almost entirely superseding the mass-polymerization method.

It is appropriate at this stage to recall that in the account[130] on the production of synthetic rubbers at Schkopau, in Germany, published on the eve of the outbreak of the present war, it has been stated that the most efficient method for polymerizing butadiene and butadiene plus styrene was found to be the emulsion process. This means that the best way for obtaining synthetic rubber in this case is via latex systems, with the subsequent coagulation of rubber-like substance by acetic acid.

Some idea of the utility of the emulsion method is given by the fact that out of the normal volume of the annual American consumption of the natural rubber in 1939 approximately 5 per cent. was used in the form of latex.[131]

Uses of Synthetic Latices

It may, therefore, be timely and of interest to survey the recent trend in the development of latex systems and their industrial utilization.

As is known, the application of rubber latex has the advantages of simplifying and cheapening the production scheme, obviating the need for hazardous and costly solvents (benzene, etc.), improving the conditions of labour, and requiring no installation of heavy plant for the preparatory operations. At the same time the quality of articles produced from the latex is superior to that of products from the coagulated rubber.

At the present time the latex (on a larger or smaller scale) is used for the following purposes:—

(i) Rubberizing textiles, including woven fabrics for the aeronautical service, namely, the materials for dirigibles, balloons, etc., cords for making tyres, fire hoses and the like.

(ii) The production of various articles by dipping, electro-deposition, pressure moulding, casting, etc.

(iii) The preparation of varnish and lacquer bases, coating and impregnating media, with or without modifying agents, such as fillers, pigments, etc.

(iv) The manufacture of electrical insulating materials, microporous ebonite, composite asbestos products, laminates and others.

(v) The preparation of glues and cements (in particular for the leather industry, footwear, etc.).

(vi) The manufacture of synthetic leather and leather substitutes.

(vii) Paper making, floor coverings and numerous other compositions.

Side by side with natural latex, synthetic latex is also used, the development of which in Germany, U.S.A. and Russia has lately been extraordinarily rapid. In German practice the derivation of the latex-like systems is effected by co-polymerizing butadiene (prepared by the limestone-coke-acetylene route) either with (a) styrene or (b) acrylonitrile, the former products being designated as Buna S (constituting the bulk of the marketable material), and the latter known as Buna N or Perbunan.

In the U.S.A. the production of synthetic latices is mainly realized by the co-polymerization of butadiene (obtained chiefly from petroleum by-products, butane and butenes[132]) with styrene, the nitrile of acrylic acid and methyl methacrylate. According to Egloff,[133] of the Universal Oil Products Co., the petroleum industry of the United States is in a position now to supply the raw materials to produce butadiene and styrene at the rate of 85 billion pounds a year, without lessening output of any of the other commodities required for peace-time or defence.

The close analogy between the polymerizing behaviour of styrene and that of butadiene and isoprene, which in the liquid phase also form long-chain polymers, affords the opportunity for so blending them by the co-polymerization as to yield new products with improved properties.

As may be readily appreciated, this versatility and mixing characteristics of styrene open up numerous avenues not merely in the evolution of new plastics but also in their technique of application.

According to available information, the

introduction of the benzene nucleus into the butadiene molecule results in markedly superior properties of cross-polymers; thus, for instance, Buna S latex possesses a series of valuable features, by virtue of which it can furnish not only the substitute for the natural rubber, but in certain respects even excel it. Experience shows that co-polymers from Buna S have the resistance to abrasion approximately 30 per cent. greater than vulcanizates from the natural rubber, an aspect of vital bearing upon the preparation of the insulating coating media for the electric cable industry, for the manufacture of abrasives, driving and conveyor belts, automobile tyres, etc.

The range of artificial latices has now been extended by achieving the production of neoprene latex, which forms an excellent substitute for the natural rubber latex, being utilizable without special modifications in technique for the fabrication of manifold articles.

The work on artificial latices in Russia is also illuminating, coinciding, in the main, with the recent drive for the development of synthetic rubbers. The results of studies conducted since 1935 at the Rubber Research Institute under Professor Dogadkin resulted in 1939 in the experimental production of latex from divinyl, followed shortly by the expansion of its full-scale manufacture in 1940.

Simultaneously, a practical work was carried out on utilizing the latex-like media in various fields of technology, and the experiments have demonstrated not only the possibility but desirability of application of synthetic latices in the production of a series of superior leather substitutes, varnish and bonding compounds for the electrical industry. It has been found that synthetic latices can be utilized for the same purposes as the aqueous dispersion of the virgin rubber, revertex, or rubber cement. At the same time it has been established that there is a complete feasibility for switching over to synthetic latices of such manufactures as leather-like articles for both the light and heavy service.

The next notable advance was the evolution in 1940 of the synthetic latex from chloroprene, which yielded products with serviceability equivalent to the divinyl latex.

Further studies considerably enlarged the scope of leather-like compositions, the preparation of which can be based on synthetic latices, e.g., soft, fine leather-like materials and trimmings, upholstery stock, technical cardboard and fibre, and others.

It was found that in nearly all cases the introduction of latex-like systems results in substantial advantages, particularly in application to the rubber and leather industries, where it gives an immediate and very great economy in high-priced solvents, e.g., benzene, etc. For example, such a well-known composite product as brake lining, prepared from asbestos fibres saturated with the benzene rubber solution, can be effectively replaced by the pressure-moulded asbestos mass impregnated with synthetic latex. Similarly made asbestos discs may be used for facing clutches, and canvas or other fabrics are converted by the impregnation into conveyor and elevator belting, and many other products of utility.

(To be continued)

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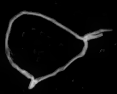
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